

# START 3

Superfund Technical Assessment and Response Team 3 -  
Region 8



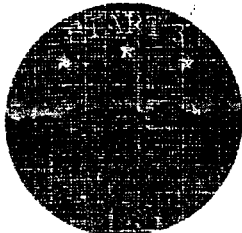
United States  
Environmental Protection Agency  
Contract No. EP-W-05-050

## WATER TREATMENT EVALUATION REPORT

GLADSTONE TREATMENT PLANT TBA  
San Juan County, Colorado

TDD No. 0509-41

SEPTEMBER 14, 2006



**URS**  
OPERATING SERVICES, INC.

In association with:

TechLaw, Inc.  
LT Environmental, Inc.  
TN & Associates, Inc.  
Garry Struthers Associates, Inc.

**WATER TREATMENT EVALUATION REPORT**  
**GLADSTONE TARGETED BROWNFIELDS ASSESSMENT**  
**Gladstone, San Juan County, Colorado**

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## EXECUTIVE SUMMARY

Water quality in Cement Creek and the Animas River has been impacted by historic mining activities, and despite completion of many projects that reduced the impact of the contamination, water quality improvement in Cement Creek and the Animas River is still required. EPA funded URS Operating Services, Inc. (UOS) to perform a Targeted Brownfields Assessment (TBA) to assist San Juan County, Colorado, and the Animas River Stakeholders Group (ARSG) in evaluating potential options to treat the metals laden water. This report is the second of two reports prepared for the TBA. The first was a Sampling Activities Report presenting surface water flow rate measurements and water quality data collected in 2005 from adits, streams, and a tunnel near Gladstone. These data were used to estimate the potential benefit of treating water from various sources of contaminated water and in estimating the benefit of treating those sources. This report presents an evaluation of water treatment technology alternatives, then provides a conceptual design and preliminary cost estimate for a water treatment plant (WTP). EPA and UOS met regularly with ARSG before and during the project and ARSG provided input at critical phases of the project, particularly for the selection of source water for sampling, determination of criteria for selecting a water treatment technology, selection of the water treatment technology, identification and selection of influent water sources for treatment, and selection of parameters used for the conceptual design and preliminary cost estimates for a WTP. ARSG input was critical to completion of this project.

ARSG identified several Upper Cement Creek water sources known to contribute high loads of heavy metals to the Animas River watershed. Treatment of Cement Creek at Silverton was quickly eliminated because of the high cost of treating the entire volume of water at this location. Treatment of specific water sources near Gladstone, including mine adits, the American Tunnel, and Cement Creek, was then considered. Three field surface water sampling events were conducted in July, September, and November 2005 at as many as fourteen stream, adit, and tunnel locations to collect current flow rate and water quality data from the identified sources. Data had been collected prior to completion of nearby reclamation projects and bulkhead installation in the American Tunnel and may not reflect current conditions. The 2005 data were evaluated in conjunction with historic data to identify two water collection alternatives that would provide the highest reduction in metal load for the amount of water treated: discrete collection of water discharged from the Mogul, Red and Bonita, and Upper Gold King 7<sup>th</sup> Level adits, and the American Tunnel (Water Collection Alternative 1), and diversion of Cement Creek water at or near Gladstone (Water Collection Alternative 2). Flow rates measured during July and September 2005 were used to estimate the flow rate for Water Collection Alternative 1 because previous adit discharge data were collected prior to American Tunnel bulkhead installation. Both historical and 2005

data were used to estimate the flow rate for Water Collection Alternative 2. Flow rates for Water Collection Alternatives 1 and 2 were estimated at 500 gallons per minute (gpm) and 1,200 gpm, respectively.

Water treatment technologies were evaluated for applicability and the High Density Sludge (HDS) chemical precipitation technology using lime as the neutralization agent was identified as the most applicable process for the Gladstone site given the criteria provided by ARSG. It is the most proven process for treating high flow rate, low pH, high metals content water in a limited space. HDS technology has been used to treat acid mine drainage (AMD) water at mine sites in Canada and the United States for over thirty years. Recently this technology was selected for implementation at the Summitville Superfund site in Colorado, the Horseshoe Bend site in Butte, Montana, and the Gilt Edge Mine site in South Dakota. An HDS water treatment plant offers several advantages over the previous Gladstone lime treatment system that used settling ponds to remove precipitated metals from the treated water. Among the advantages are higher sludge density (25 percent solids or higher compared to 2 percent solids generated in the settling ponds), ability to operate unmanned, and improved lime utilization efficiency.

Two conceptual designs for an HDS WTP were prepared by Canadian Environmental and Metallurgical, Inc. (CEMI) using modeling software developed from years of experience in HDS design and construction projects. One conceptual design was prepared for each of the water collection alternatives. Process parameters used in the conceptual design and cost estimation modeling were based on historic and existing site conditions and water quality discharge standards applied to the previous WTP. Influent water quality, sludge production, and other model inputs were based on a treatability study performed on water collected during September 2005. An operating pH of 9 was selected as a balance between metal removal costs and operation and maintenance (O&M) costs, both of which increase at a higher operating pH.

Based on the conceptual design, CEMI estimated the process oriented costs for constructing and operating an HDS WTP. Additional costs were estimated by a URS cost estimator and included site development, WTP design, water collection systems, sludge disposal, and other operational costs. Two sludge disposal options were evaluated: transportation and disposal at a yet to be identified location near Silverton (Option 1) and transportation and disposal at the Bondad municipal landfill located south of Durango (Option 2). ARSG requested that two potential WTP locations be evaluated: U.S. Bureau of Land Management (BLM) land at Gladstone (Location 1) and the Success Placer located approximately ½ mile north of Gladstone along Cement Creek (Location 2).

The capital and O&M costs to construct and operate the proposed WTP were tabulated for each combination of water collection alternative, sludge disposal option, and WTP location, resulting in eight scenarios. Because many factors that will affect the ultimate capital and O&M costs of a WTP constructed for this project have not been determined, the estimates prepared for this report are presented as ranges. The high-range costs include optional features such as a surge pond and a buried water collection system; the lower-end costs include essential features only. An inflation factor of four percent is applied to the O&M costs and a discount rate of eight percent was assumed in order to perform net present value (NPV) calculations. Assuming a 20 year project life, the NPV costs for construction, operation, and maintenance of a WTP given the eight scenarios range from \$9.7 million for a WTP located at Gladstone using Water Collection Alternative 1 and sludge disposal option 1 but with no optional site development costs to \$15.9 million for a WTP location at the Success Placer using Water Collection Alternative 2, sludge disposal option 2 and including all of the optional site development features.

The benefits of installing a WTP at or near Gladstone are difficult to determine because of the complex water geochemistry and variable basin hydrology. Historic adit discharge and surface water quality and flow rate data are limited and not all data are applicable to existing and future site conditions due to completion of reclamation projects, installation of bulkheads in the American Tunnel and elsewhere, and discontinuation of water treatment at Gladstone since the data were collected. The U.S. Geological Survey (USGS) has identified both natural and anthropogenic sources of contamination and a complex geochemical system downstream of Gladstone, further confounding prediction of water quality improvements that may be observed once a WTP is installed at Gladstone. For the purposes of this report, calculations were performed using simplifying assumptions to predict, in general, the benefit of construction and operation of a WTP for water quality at CC48 and A72, USGS gauging stations located on Cement Creek near Silverton (CC48) and on the Animas River immediately downstream of Silverton (A72). Calculations were performed assuming that the amount of metals removed at Gladstone could be subtracted from CC48 and A72 metals loads. The results indicate that the reduction in metals concentrations at A72 would vary significantly depending on the specific metal and the time of year. The effects of water treatment would be more significant during base flow than during late spring runoff. The mass balance calculations indicate that concentrations of the contaminants of concern at A72 would decrease by an average of approximately 30 percent. Continued adit and stream water quality and flow rate monitoring and modeling are highly recommended to provide data necessary for effective WTP design and evaluation of anticipated water quality improvements at A72.

**TABLE ES-1**  
**Gladstone High Density Sludge (HDS) Water Treatment Plant**  
**Cost Estimate Summary**

Scenario	Water Collection Alternative	Sludge Disposal Option	WTP Location	Low-Range Capital Cost	High-Range Capital Cost	Annual Cost	Low-Range Net Present Value Cost Estimate	High-Range Net Present Value Cost Estimate
1	Adits/Tunnel	Near Silverton	Gladstone	\$4,260,000	\$6,200,000	\$409,000	\$9,700,000	\$11,600,000
2	Adits/Tunnel	Bondad Landfill	Gladstone	\$4,260,000	\$6,200,000	\$483,000	\$10,700,000	\$12,600,000
3	Adits/Tunnel	Near Silverton	Success Placer	\$4,790,000	\$6,030,000	\$465,000	\$10,900,000	\$12,200,000
4	Adits/Tunnel	Bondad Landfill	Success Placer	\$4,790,000	\$6,030,000	\$539,000	\$12,000,000	\$13,200,000
5	Cement Creek	Near Silverton	Gladstone	\$5,760,000	\$7,780,000	\$490,000	\$12,200,000	\$14,300,000
6	Cement Creek	Bondad Landfill	Gladstone	\$5,760,000	\$7,780,000	\$568,000	\$13,300,000	\$15,300,000
7	Cement Creek	Near Silverton	Success Placer	\$6,330,000	\$7,650,000	\$546,000	\$13,600,000	\$14,900,000
8	Cement Creek	Bondad Landfill	Success Placer	\$6,325,000	\$7,650,000	\$624,000	\$14,600,000	\$15,900,000

## 1.0 INTRODUCTION

This Water Treatment Evaluation Report was prepared by URS Operating Services, Inc. (UOS) for the U.S. Environmental Protection Agency (EPA) in accordance with Superfund Technical Assessment and Response Team 2 (START2) and START 3 contract requirements and Technical Direction Documents (TDD) 0505-0008 and 0509-41. The report provides an evaluation of water treatment options for contaminated waters that enter Cement Creek upstream of and near the former mining town of Gladstone, Colorado.

This work was funded by EPA as a Targeted Brownfields Assessment (TBA) at the request of San Juan County and the Animas River Stakeholders Group (ARSG). Over the past 12 years, various agencies, business owners, and community groups, under the guidance of ARSG, have facilitated numerous activities to reduce the impact of historic mining on the Cement Creek/Animas River watershed. EPA is funding the work presented in this document to assist San Juan County in studying the potential for construction of a new plant to treat water from the American Tunnel and other mines in the area. Concurrent to this water treatment evaluation, efforts are being made by ARSG, the U.S. Bureau of Land Management (BLM), state and federal agencies, and government officials, to allow the treatment plant to be constructed and operated without incurring liability under the Clean Water Act. Several versions of a "Good Samaritan" amendment to the Clean Water Act are currently before the U.S. Congress to meet this end. Additionally, the BLM and San Juan County have conducted an assessment of potential ownership/operating scenarios that will allow for the most effective management for the water treatment project. UOS received invaluable input and technical assistance from ARSG during the project. The work presented here was conducted with ARSG concurrence, including approval of the project direction at critical junctures.

Water in upper Cement Creek contains high levels of metals and acidity from runoff over mine waste rock, mine discharges, and natural processes in this mineral rich zone. Mine discharge from the American Tunnel and the Gold King Mine 7<sup>th</sup> Level was being treated by Gold King Corporation (GKC) under a Colorado Department of Public Health and Environment (CDPHE) permit; however, due to legal issues and financial limitations, GKC discontinued treatment in August 2004. In addition to American Tunnel water that now flows from the American Tunnel into Cement Creek without treatment, other upstream mines contribute to the metals load in Cement Creek and ultimately the Animas River. Water treatment is expected to result in reduced metal loading to Cement Creek and the Animas River, increasing the potential for the Animas River to meet water quality standards downstream of the Cement Creek confluence.

This report presents a brief site history, a summary of water quality at area mines and upper Cement Creek based on three 2005 sampling events conducted by UOS, a summary of potential water treatment options, selection of a High Density Sludge (HDS) Lime Precipitation process for water treatment, a discussion of process options, a summary of bench tests and analyses performed to assist in determining water treatment plant parameters, evaluation of water collection alternatives, evaluation of water treatment parameters for use in cost estimation, a conceptual design, an estimation of costs for constructing and operating an HDS water treatment plant, and suggestions for next steps. This report does not provide water treatment design. The primary water treatment plant cost estimate was performed by Canadian Environmental and Metallurgical, Inc. (CEMI). Costs not included in the CEMI report were estimated based on two sludge disposal options selected by ARSG, one at an unknown location at Silverton and one at the Bondad Landfill near Durango, and two potential Water Treatment Plant (WTP) locations identified by ARSG, one located on BLM property at Gladstone and the other located on the Success Placer located approximately 0.3 miles northwest of Gladstone.

## **2.0 BACKGROUND**

The information provided here is not a compendium of all existing studies because of the extent of work that has been conducted in the Animas watershed. This section presents background and history relevant to determining an effective water treatment scenario at Gladstone.

### **2.1 LOCATION AND SITE HISTORY**

The Gladstone site is located near the former mining town of Gladstone, Colorado, and includes waters that are contaminated from historic mining activities upstream. Gladstone is located approximately 8 miles north of Silverton, in San Juan County, Colorado, within the San Juan mountain range of the Rocky Mountains at an elevation of 10,500 feet. Gladstone is located within 1½ miles of the Silverton Mountain Ski Area. Long cold winters and short cool summers characterize the climate at Gladstone, winter snowfall is heavy and thunderstorms are common in the summer. The site averages more than 25 inches of precipitation a year. Temperatures range from a high of 80 degrees Fahrenheit (°F) and a low of 20°F in the summer to a high of 40°F and low of -10°F in the winter).

Gladstone is a historic mining town that was developed in the 1880s and is now abandoned. Mining has occurred near Gladstone since the 1880s. The last operating mill in Gladstone closed in the 1950s,

but mining continued until 1991. The largest mine in the Animas Mining District was the Sunnyside Mine which is now nearing completion of final reclamation. The Gold King Mine is currently inactive. Both mines were partially accessed through the American Tunnel that has its portal at Gladstone. Three bulkheads were placed in the tunnel on September 9, 1996, August 31, 2001, and December 3, 2002, to reduce water discharges that had peaked at 1,600 gallons per minute (gpm). Current discharge from the American Tunnel is approximately 100 gpm. Other mines in the area also contribute significant loads of metals, including aluminum, cadmium, copper, iron, lead, manganese, and zinc, to Cement Creek and ultimately the Animas River. Sites identified by ARSG as high priority, high metal concentration, high acidity, low volume contributors include Eveline, Gold King 7<sup>th</sup> Level, Mogul, Grand Mogul, Joe and John, Silver Ledge, and Red and Bonita. Cement Creek water from upstream carries high metal loads and acidity from natural processes and other upstream mines. (Based on "Gladstone Treatment Plant Assessment, a Targeted Brownfield Assessment Project Proposal" (San Juan County 2005))

## 2.2 SITE WATER TREATMENT HISTORY

A WTP was installed at Gladstone in 1979 by Standard Metals Corporation to treat water (approximately 1,600 gpm discharging from the American Tunnel. Initially the WTP consisted only of sedimentation ponds. Within a few years the WTP was upgraded to include quick lime addition to raise the pH of the water and precipitate metals (Larry Perino 2006). Water from Minnehaha Creek was diverted to the WTP and used to hydrate the lime before it was added to the treatment water. Polymer was added to improve the solids settling properties. Four unlined sedimentation ponds located on the Herbert Placer were used to separate the water from the solids. Effluent water from the fourth pond was discharged to Cement Creek. The sludge was periodically removed from the ponds and hauled to the Mayflower No. 4 Tailings Pond. The discharge was permitted by the Colorado Health Department (now CDPHE) under permit # CO-0027529.

Sunnyside Gold Corporation (SGC) purchased Standard Metals' interests in 1985 and continued active mining until 1991. The discharge permit standards were lowered in 1986 (Perino 2006). Current discharge standards are listed in Table 3. Water treatment activities continued as before and active mine reclamation began in 1991. The operation and maintenance (O&M) costs for the WTP were reported to be \$500,000 per year (University of Colorado 2000).

On May 8, 1996, a Consent Decree was signed by SGC, CDPHE Water Quality Control Division (WQCD), and the Colorado Division of Mining and Geology (DMG) that adopted a watershed

approach to water quality improvement. The Consent Decree was eventually amended four times to incorporate specific plans as they were developed. It was determined that perpetual water treatment was not viable. SGC agreed to perform reclamation projects within the watershed so that water treatment at Gladstone could be stopped without a net increase in metal loading at A72. Many of the projects involved removal of mine waste and tailings that contained high metals concentrations and that were leaching metals to surface waters (Sunnyside Gold Corporation (SGC) 2004). Another component of the Consent Decree was installation of a Cement Creek diversion structure to allow water from Cement Creek to be treated in the WTP when American Tunnel discharges decreased after the placement of bulkheads.

SGC projects in upper Cement Creek included the installation of three bulkheads in the American Tunnel and one bulkhead installed in the Terry Tunnel. The bulkheads were installed to limit the flow of acid mine drainage (AMD) water and return area hydrogeology to as near pre-mining conditions as possible. American Tunnel Bulkheads No. 1, No. 2, and No. 3 were closed on September 9, 1996, August 31, 2001, and December 3, 2002, respectively (Perino 2006). The Terry Tunnel bulkhead was closed on October 5, 2000 (Colorado Department of Public Health and the Environment (CDPHE) 2003; CDPHE 2005). Based on pressure gauge measurements, the Colorado DMG determined that the mine pool reached equilibrium in November 2000, approximately four years after the installation of the first bulkhead. Flow from the American Tunnel decreased after each bulkhead was closed, ultimately to less than 100 gpm. In accordance with the Consent Decree, the WTP throughput was maintained at approximately 1,600 gpm by adding water from Cement Creek to the American Tunnel discharge. During low flow periods, WTP throughput was less than 1,600 gpm.

Documentation of SGC WTP performance from January 1998 to December 2002 was reviewed for this report. The data indicate that the water was treated to a pH of 9 to 10 and average monthly throughput ranged from 347 gpm to 1,639 gpm (U.S. Environmental Protection Agency (EPA) 2006). Sample results indicate that WTP effluent easily met discharge standards.

On January 13, 2003, CDPHE determined that the Consent Decree conditions had been met and approved the transfer of the National Pollutant Discharge Elimination System (NPDES) permit from SGC to GKC. (The NPDES permit was subsequently renewed in GKC's name.) GKC installed 3,500 feet of piping from the Gold King Mine 7<sup>th</sup> Level adit to the WTP. Water from the American Tunnel and Gold King Mine 7<sup>th</sup> Level adit was treated at the WTP. Treatment of Cement Creek water was apparently stopped by June 2003. In July 2003, the Consent Decree was terminated (CDPHE 2005). As part of a land and financial settlement between GKC and SGC, GKC installed a bulkhead in the Mogul Mine in 2003 that reduced the discharge rate from 130 gpm to 27 gpm (URS Operating



Services, Inc. (UOS 2006). It had been suggested that the Mogul discharge rate had increased due to bulkheads installed in the American Tunnel.

GKC treated water from the American Tunnel and Gold King Mine 7<sup>th</sup> Level at a monthly average rate of 104 to 167 gpm from June 2003 until September 2004. NPDES reports indicate that the water was treated to a wider pH range than previously (7 to 10). On September 23, 2004, CDPHE issued GKC a Notice of Violation based on WTP effluent sample results that exceeded permit standards and a failure to monitor effluent parameters. Subsequently, legal disputes arose between GKC and San Juan Corporation, who had obtained from SGC ownership of the land occupied by the sedimentation ponds, and WTP operations have not restarted. In November 2005, SGC removed the sedimentation ponds to meet the requirements of the DMG Reclamation Board. Land occupied by the WTP equipment is scheduled for reclamation in 2006. (See Section 7.1.1, Use of Existing WTP Equipment.) GKC recently deeded the WTP equipment to the state of Colorado.

### 3.0 WATER QUALITY

The primary goal of a WTP at the Gladstone site is to reduce metals loading to assist in meeting the state water quality standards at the A72 gauging station. Cement Creek is contaminated with metals from both natural and anthropogenic sources, and while many sources of contamination have been mitigated, many sources remain, including discrete and dispersed adit discharges and natural sources.

This section presents current and proposed water quality standards in Cement Creek and the Animas River downstream of the Cement Creek confluence, a brief summary of historic water quality conditions focused on aspects that may impact water treatment options, and a description of how the effectiveness of water treatment options will be evaluated for purposes of this report.

#### 3.1 WATER QUALITY STANDARDS

State water quality standards for Cement Creek and the Animas River are found in the Colorado Code of Regulations 5 CCR 1002 Regulation 34: "Classification and Numeric Standards for San Juan River and Dolores River Basins." This regulation was last reviewed in June 2006. Standards that will apply as of January 2007 to Cement Creek (Segment 7, measuring point CC48) and the Animas River downstream of Mineral Creek (Segment 4a, measuring point A72) are listed on Table 1. Standards that vary by month are provided in Table 2. Table Value Standards (TVS) not listed in the following

table are formulas based on water hardness. TVSs calculated for varying hardness conditions are presented in Table 3.

The standards for stream segments 4a and 7 have temporary modifications that will expire on December 31, 2011. Temporary modifications are shown in brackets on Table 1.

**TABLE 1**  
**Metals and pH Water Quality Standards (WQS) at Animas River Segments 4a and 7**  
**(Concentrations in micrograms per liter (µg/L) unless otherwise noted**  
**Metal concentrations are dissolved metals unless otherwise noted)**

	<b>Stream Segment 7 (Acute)</b>	<b>Stream Segment 7 (Chronic)</b>	<b>Stream Segment 4a (Acute)</b>	<b>Stream Segment 4a (Chronic)</b>
Aluminum	To maintain and achieve WQS at Segments 4a and 4b	--	Monthly standards	Monthly standards [2523 (TRec)]
Arsenic	--	100 (TRec)	340	100 (TRec)
Beryllium	--	100 (TRec)	--	--
Cadmium	To maintain and achieve WQS at Segments 4a and 4b	10 (TRec)	TVS (trout)	TVS [2.5]
Chromium III	--	100 (TRec)	TVS	TVS
Chromium VI	--	100 (TRec)	TVS	TVS
Copper	To maintain and achieve WQS at Segments 4a and 4b	200 (TRec)	TVS	TVS [20]
Iron	To maintain and achieve WQS at Segments 4a and 4b	--	Monthly standards (see Table 2)	Monthly standards [4204 (TRec)]
Lead	To maintain and achieve WQS at Segments 4a and 4b	100 (TRec)	TVS	TVS
Manganese	To maintain and achieve WQS at Segments 4a and 4b	--	TVS	TVS
Mercury	--	--	--	0.01 (Total)
Nickel	--	200 (TRec)	TVS	TVS
Selenium	--	20 (TRec)	TVS	TVS
Silver	--	--	TVS	TVS (trout)
Zinc	To maintain and achieve WQS at Segments 4a and 4b	2000 (TRec)	Monthly standards	Monthly standards [730]
pH	3.7 – 9.0	--	--	Monthly standards [Existing quality]

TRec Total recoverable metals concentration  
 TVS Table Value Standard  
 WQS Water Quality Standards

**Animas River Stream Segment 4a is the Animas River between the confluence with Mineral Creek to the confluence with Deer Park Creek. Temporary modifications for Stream Segment 4a are shown in brackets [ ].**

**Animas River Stream Segment 7 is Cement Creek and its tributaries. Stream Segment 7 has a temporary modification to existing quality for all metals.**

**TABLE 2**  
**Monthly Table Value Standards for the Animas River Basin Segment 4a**  
 (Concentrations in micrograms per liter (µg/L) unless otherwise noted)

Month	Total Recoverable Aluminum (Acute and Chronic)	Dissolved Iron (Chronic)	Dissolved Zinc (Acute and Chronic)	pH (standard units)
January	3,100	3,473	460	5.9 to 9.0
February	3,550	2,961	520	5.7 to 9.0
March	2,800	3,776	620	6.2 to 9.0
April	2,020	3,404	570	6.5 to 9.0
May	1,010	2,015	430	6.5 to 9.0
June	740	1,220	250	6.5 to 9.0
July	700	1,286	170	6.5 to 9.0
August	1,360	1,830	240	6.5 to 9.0
September	1,490	1,623	290	6.5 to 9.0
October	1,610	2,258	340	6.5 to 9.0
November	2,280	2,631	380	6.5 to 9.0
December	2,570	3,511	420	5.9 to 9.0

$23230 \times 1/12 = 1936$        $29988 \times 1/12 = 2499$        $4690 \times 1/12 = 391$   
 Avg                      Avg                      Avg

**TABLE 3**  
**Selected Colorado Table Value Standards and Previous Gladstone Treatment Plant NPDES Standards**  
 (Concentrations in micrograms per liter (µg/L))

	Acute TVS (hardness = 200/400)	Chronic TVS (hardness = 200/400)	Previous Gladstone Treatment Plant Standards	
			Daily Maximum	30-Day Avg. Limit
Cadmium	3.1/5.7	0.72/1.2	100	050
Chromium III	1005/1773	130/230	--	--
Chromium VI	16	11	--	--
Copper	25.9/50	0.0162/0.029	300	150
Lead	140/280	5/11	600	300
Manganese	3700/4700	2100/2600	--	--
Nickel	842/1513	93/168	--	--
Selenium	18.4	46	--	--
Silver	6.7/22.0	0.25/0.81	--	--
Zinc	260/470	224/405	1500	750

Note: Colorado Table Value Standards (TVS) are numerical criteria set forth in "Basic Standards and Methodologies for Surface Water", Colorado Water Quality Control Commission Regulation 31. As shown in Tables 1 and 2, these standards are not all directly applicable to Cement Creek and the Animas River, but they can be used as a point of comparison in determining the quality of water discharged from a water treatment plant at Gladstone.

### 3.2 HISTORIC WATER QUALITY AND STUDIES

Many studies have been performed on waters in the Cement Creek and Animas basins. The Use Attainability Analysis (UAA), prepared by ARSG in 2001, provides a summary of water quality studies and issues and was used as the primary source of information for this section. The UAA was performed to fulfill requirements of the Clean Water Act for use in promulgating use classifications, water quality standards, segment descriptions, and Total Maximum Daily Loads (TMDLs). The UAA was prepared while discharge from the American Tunnel and, at times, Cement Creek, were being treated by SGC and does not include analysis of conditions since water treatment was reduced or discontinued. Therefore, while the information is very useful for understanding contaminant sources and transport in the system, it is of limited usefulness in preparing quantitative analyses to determine the effect of treating adit and/or Cement Creek water at Gladstone. Additional studies that are relevant to predicting water quality at A72 after installation of a WTP at Gladstone are discussed in the next section.

The UAA indicates that aluminum, cadmium, copper, iron, manganese, and zinc exceed water quality standards in the Animas River. Data from Cement Creek at Silverton (CC48) indicate that the highest levels of aluminum, iron, manganese, and zinc are observed during base flow, but the highest concentrations of copper occur during runoff. The pH of Cement Creek is less than 5.0 for all seasons and stream flows. Aluminum, cadmium, copper, lead, and zinc are present throughout Cement Creek in levels that would be acutely toxic to aquatic life. Data from the Animas River downstream of Mineral Creek (A72) indicate that cadmium and copper exceed chronic TVS during portions of the year, aluminum exceeds chronic standards during base flow, and zinc exceeds both acute and chronic TVS year round and exceeds the temporary modification adopted by the WQCC during base flow. Significant reductions in contaminant concentrations have been observed during parts of the year since remediation activities were performed by SGS, ARSG, and others (Animas River Stakeholders Group (ARSG) 2001)

The UAA analyzes sources of metals and acidity in the basin. Only about half of the zinc load in Cement Creek was from identifiable tributary and mine sources. Downstream of Gladstone, groundwater, relatively unimpacted by mining, appears to be a source of aluminum, copper, iron, and zinc in Cement Creek during base flow, but contributes a minor portion of these contaminants during

runoff months. The data used in this analysis were collected during water treatment at Gladstone. (ARSG 2001)

Generally, discharge from most adits is believed to be relatively constant throughout the year. High flow is seldom twice that of low flow. The percentage contribution of metals from adits and mines is highest during base flow because of the lack of dilution from snowmelt. Discharge from adits was shown to have little effect on the concentrations of most metals during the runoff months of May through October. Again, the data used in this analysis was collected during water treatment at Gladstone. Treatment of Cement Creek between 1996 and 1999 lowered the average concentration of copper and zinc at CC48 by 15 µg/L and 212 µg/L, respectively. (ARSG 2001)

Several of the conclusions of the UAA evaluation of the water quality and sources of degradation may be applicable to the effectiveness of treating water at Gladstone. Nearly all the total recoverable aluminum measured at A72 is attributed to groundwater sources rather than discrete adits or seasonal runoff. Controlling sources of iron from adits and seasonal runoff could improve water quality but TVS criteria could not be met most of the time. Zinc levels could be substantially reduced if sources from adits and seasonal runoff were controlled. It is unlikely that acute and chronic TVS criteria can be met at A72 during the months of October through April. Dissolved copper has been suggested as a possible limiting factor for brook trout. Controlling sources of copper from adits or seasonal runoff should enable the segment to meet the aquatic life criteria. (Section 8 of ARSG 2001) These statements indicate that a WTP at Gladstone may significantly reduce zinc and copper concentrations at A72, somewhat reduce iron concentrations at A72, and minimally reduce aluminum concentrations at A72.

Sampling in September 1996 indicated that the area above the American Tunnel accounted for about 18 percent of the dissolved zinc and 40 percent of the dissolved copper load at Cement Creek at Silverton as measured at CC48 (U.S. Geological Survey (USGS) 2000). During water treatment, the zinc concentration at CC48 was reduced by about 20 percent and the copper concentration was reduced by as much as 54 percent. Large quantities of aluminum, iron, and zinc were observed to enter Cement Creek downstream of Gladstone. Data from CC48 show reduced levels of cadmium and manganese after treatment of Cement Creek above the American Tunnel began in October 1996. No changes in the levels of dissolved aluminum or iron were observed at Silverton after treatment began.

The highest concentrations of aluminum, iron, manganese, and zinc were observed during base flow, but the highest concentrations of copper were observed during peak runoff (ARSG 2001).

Cement Creek and the Animas River downstream of Cement Creek (and other waterbodies in the region) are included on the Colorado Section 303(d) list of waterbodies in need of TMDLs. In order for water quality standards to be met, TMDLs were developed to allocate allowable contaminant loading to various sources. TMDLs were developed for aluminum, cadmium, copper, iron, and lead *Line ?* in Cement Creek and for the Animas River between Cement Creek and Mineral Creek. The water quality goal for the TMDLs is attainment of the adopted Aquatic Life Use Classifications for segments 3a, 4a, 4b, and 9. TMDLs for three measuring points (A68, MC34, and A72) were calculated based on achieving water quality standards.

Sixty-five remediation projects were identified by ARSG in the UAA and four feasibility reports that were prepared by DMG to meet the requirements for TMDL implementation (ARSG 2001). TMDLs for CC48 were calculated by subtracting anticipated load reductions from the 65 remediation projects from existing conditions. The TMDL states that the ARSG remediation plans, if completed, should achieve the water quality goals and targets within twenty years. Metals loading was expected to be reduced by approximately 50 percent by bulkhead installation, 30 percent by passive treatment, 85 percent by active treatment, or 50 percent by infiltration source control. The remediation goals outlined by ARSG in the UAA are the basis for implementation of the TMDL.

Numerous projects have been completed in the watershed by the U. S. Bureau of Land Management (BLM), SGC, ARSG, and others from 1998 to the present. These projects have likely improved water quality at A72 over the past 10 years. Conversely, discontinuation of water treatment at Gladstone has likely degraded water quality at A72.

### 3.3 ESTIMATING THE EFFECTIVENESS OF WATER TREATMENT

The primary goal of water treatment is to reduce the metal load at A72; however, it is difficult to evaluate the effect of various water treatment scenarios on A72 water quality. A simple mass balance may not accurately account for all of the effects of increased alkalinity and reduced metal concentrations in Cement Creek from water treatment at Gladstone. There are many factors that affect water quality at A72 besides water quality in Cement Creek at Gladstone.

U.S. Geological Survey (USGS) studies have indicated that Cement Creek is a complex system. The USGS performed tracer studies and synoptic sampling in the watershed to determine loading. The results were used in an OTIS (One-dimensional Transport with Inflow and Storage) and (OTEQ (One-dimensional Transport with Equilibrium Chemistry) models to assist in evaluation of remediation alternatives. Unfortunately these studies were conducted in 1996 and 1999 during operation of the former treatment system so it is difficult to evaluate changes that may have occurred due to bulkhead installation and discontinuation of treatment. It may be helpful to redo some of this work to allow update of the model so the effects of the new water treatment system could be evaluated; however, that is not within the scope of work of this project and will not be attempted here.

Another way to determine the effect of installing a water treatment system on water quality at A72 is to look at how previous changes at Gladstone affected A72 water quality. Measured changes in water quality caused by initiation of water treatment in 1979, installation of bulkheads in 1996, 2001, and 2002, and subsequent reduction/discontinuation of water treatment beginning in 2003 could be used to predict water quality changes expected after installation of a new water treatment system. According to the UAA, by 1989 the treated discharge from the American Tunnel was not a significant source of metals to Cement Creek. The effect of water treatment was not quantified so may not be used here to quantify the effects of reduced metal loading at Gladstone on water quality at A72.

Installation of the American Tunnel bulkheads and treatment of Cement Creek water reduced CC48 metal concentrations further. As stated above, a comparison of pre-1996 water quality data for CC48 or A72 with water quality data after initiation of Cement Creek water treatment at Gladstone shows the zinc concentration at CC48 was reduced by about 20 percent and the copper concentration was reduced by as much as 54 percent. Cadmium and manganese concentrations were also reduced. No changes in the levels of dissolved aluminum or iron were observed at CC48. This information suggests reduced zinc, copper, cadmium, and manganese concentrations will result from treating adit discharges and/or Cement Creek water, but that aluminum and iron concentrations may not show significant reductions. The amount of contaminant reduction is difficult to quantify using this historical comparison; however, because other factors have to be considered including other mine reclamation activities, frequent water treatment modifications, and the unknown impacts of bulkheading on the local groundwater system.

Evaluation of A72 water quality since reduction and later discontinuation of water treatment in 2004 could also assist in determining the effectiveness of a new WTP to treat adit and/or Cement Creek water at Gladstone. An evaluation of the effects of remediation on water quality that was prepared for ARSG (Robert J. Owen 2005) based on data through 2004 indicates a steady upward trend in cadmium concentrations, and potential gradual increases in zinc and aluminum concentrations. Because of the phased reduction in water treatment, bulkhead installations, and other remediation projects in the watershed, it is likely that this portion of the watershed has not reached equilibrium. Also, the system may require time to equilibrate from recent changes; an abrupt change in upstream metal concentrations may not have an immediate effect on downstream metal concentrations. Metal concentration trends at A72 would need to be evaluated over several years with consideration of water treatment, remediation projects, upstream water conditions, and a variety of other factors to effectively determine the impact of the discontinuation of water treatment. Therefore, at this time, the changes observed at A72 since discontinuation of water treatment at Gladstone will not be used to make decisions regarding the effectiveness of various water treatment scenarios.

As an alternative to an evaluation considering direct impact at A72, estimates of the load reduction at Gladstone (CC18) were used to assist in the evaluation of various water treatment scenarios described in Section 4.0. Because ARSG has requested that water treatment scenarios be evaluated based on the highest amount of metal removal for the cost, this method is considered adequate for purposes of this report. Based on input from ARSG, it is anticipated that the preferred water treatment method will be selected based on cost, effectiveness, implementability, and other factors in addition to the effect on water quality at A72. As additional water quality monitoring is performed, ARSG may be able to more precisely quantify the anticipated impact of a water treatment system on A72 water quality.

Despite these limitations, the anticipated load reductions and resulting water quality at CC48 and A72 were calculated by performing a mass balance using data from 2004 and 2005 and several simplifying assumptions. This information should be used to estimate the relative effect of water treatment and not to estimate actual metal concentrations using the given treatment method. Additional current water quality monitoring and modeling should be performed if specific concentrations expected at A72 after installation and operation of a WTP are required.



#### **4.0 POTENTIAL WATER TREATMENT TECHNOLOGIES**

Water treatment technologies may be categorized into three types: physical, chemical, and biological. The following sections provide a brief description of each type and examples of technologies within each category.

##### **4.1 PHYSICAL TREATMENT TECHNOLOGIES**

Physical treatments are based on the difference in physical characteristics of the metal contaminants and the water in which they are dissolved. Examples include filtration, based on the presence of solids or the difference in ion size; adsorption, based on the difference in attachment to a solid surface; sedimentation, based on the difference in density; and evaporation, based on the difference in boiling point.

###### **4.1.1 Filtration**

Filtration separates suspended solids from a liquid by passing the mixture through a porous medium that allows the water to pass but retains the solids. Several filter mediums can be used, including granular material and fabric. Filtration can be used to remove suspended particulate material before treatment of ionic species from contaminated water and/or to remove precipitate from the water.

Microfiltration allows removal of precipitates from a solution. Nanofiltration is similar, but allows separation of metal ions from the water. These are also considered membrane processes. There are no known large scale AMD treatment plants using this technology at this time.

Filtration processes do not remove dissolved contaminant ions from solution, and even with optimum performance result in a concentrate stream that requires further treatment and/or disposal.

#### **4.1.2 Membrane Processes/Reverse Osmosis**

Reverse osmosis is a membrane technology used to separate larger ions from a water solution. Water is forced through the membrane by application of pressure greater than the normal osmotic pressure. The properties of the membrane determine the rate of transport and the species that will pass through the membrane. Reverse osmosis and other membrane technologies are generally used as a polishing step in water treatment, but can also be used to concentrate the metal ions in solution for subsequent treatment by precipitation or other method given an appropriate membrane. This method reduces the anion concentrations (i.e., sulfate) in addition to reducing the metal ion concentrations in the effluent water. Care must be taken to prevent cake formation on the membrane. Specialized membranes and electrocharging techniques have been developed to allow for treatment of more concentrated solutions without excess membrane clogging. Membrane processes do not remove contaminant ions from solution and, even with optimum performance result in a concentrate stream that requires further treatment and/or disposal.

#### **4.1.3 Sedimentation/Clarification**

Sedimentation is the removal of suspended solids from water by gravity settling. The emphasis can be on producing a thick sludge (thickening) and/or producing a clear effluent (clarification). The operation is often aided by addition of a flocculent to assist in coagulation and settling of particles.

#### **4.1.4 Carbon Adsorption**

"Carbon adsorption" using charcoal or activated carbon can be considered both adsorption and ion exchange. Carbon adsorption is more commonly used for organic contaminants; however, some work has been done on metal removal, most commonly in removing precious metals from cyanide complexes. As water flows through a chamber packed with charcoal or activated carbon, metal ions are adsorbed onto the large surface area of the substrate. When the capacity of the substrate to adsorb ions is reached, the substrate must be regenerated, either by incineration or flushing. Continuous flow carbon adsorption has not been proven in

practice and may be difficult and expensive for treatment of waters with high metal concentrations.

#### **4.1.5 Evaporation**

Evaporation can involve heating the metal contaminated water until it evaporates. Natural evaporation in large ponds (with or without vegetation) can be used in hot dry climates with low influent flow rates, large available area for evaporation, and no requirement for discharge water. Evaporation can be enhanced by increasing water temperature and/or decreasing pressure. Increasing temperature and/or decreasing pressure would require large amounts of energy, making this technology cost prohibitive. The elimination of discharge water may be problematic if "clean" water discharge is needed to meet legal requirements or to use as dilution water to meet standards at a point of compliance.

#### **4.1.6 Solvent Extraction**

Solvent extraction uses an organic liquid mixed with contaminated water to transfer metal ions from the water to the organic liquid. The ions partition to and concentrate in the organic liquid. The organic liquid is then stripped of metals using sulfuric acid and recycled. The sulfuric acid solution must then undergo an electrolysis process (electrowinning) or crystallization. This method is particularly useful when only one metal requires removal because organic liquids are available to target specific metal ions. There are some limitations on organic compounds able to remove all of the contaminants in the Gladstone water, the potential removal capacity for each metal, and the physical conditions under which optimum contaminant removal is possible. This process can be very expensive to maintain and operate.

### **4.2 CHEMICAL TREATMENT TECHNOLOGIES**

Chemical treatment technologies are based on reactions between species that allow separation of the metal contaminants and water. Examples of chemical treatments include chemical precipitation, ion exchange, and oxidation.

#### 4.2.1 Chemical Precipitation

Chemical precipitation occurs when a reaction between two substances in a liquid solution produces a solid product. The solid product can be removed from the liquid by gravity separation, filtration, or other methods. Chemical precipitation is the most common method for removing metals from AMD/discharge and is reliable, effective, and cost-effective.

A neutralizing agent is used to increase the solution pH, causing the formation of metal hydroxide, metal carbonate, or metal sulfide precipitates, depending on the neutralization agent used. Hydroxide precipitation is effective for arsenic, cadmium, chromium (+3), nickel, zinc, manganese, copper (+2), tin (+3), and iron (+3). The most commonly used neutralizing agents are hydrated lime ( $\text{Ca(OH)}_2$ ), quick lime ( $\text{CaO}$ ), and limestone ( $\text{CaCO}_3$ ), however other agents can be applied to this process. Other reagents include sodium hydroxide ( $\text{NaOH}$ ), potassium hydroxide ( $\text{KOH}$ ), magnesium hydroxide ( $\text{Mg(OH)}_2$ ), magnesium oxide ( $\text{MgO}$ ), dolomite ( $\text{CaMg(CO}_3)_2$ ), magnesite ( $\text{MgCO}_3$ ), or soda ash ( $\text{Na}_2\text{CO}_3$ ). Sulfide precipitation may use a sulfide reagent, often sodium sulfide or sodium bisulfide, to form metal sulfide precipitate and is particularly effective in removing mercury and lead from water. Hydrogen sulfide generated by chemical or biological processes may be used for sulfide precipitation. Carbonate precipitation uses a carbonate reagent, often calcium carbonate, sodium carbonate, or potassium carbonate, to form metal carbonate precipitates and is particularly effective in removing lead, cadmium, and antimony from water. The appropriate neutralizing agent generally depends on the metals of concern, local cost and availability of materials, and the settling characteristics produced in the sludge. Other characteristics of the neutralizing agent, such as reactivity with other constituents (sulfate, iron oxide, and iron hydroxide) in the contaminated water, must also be considered.

In a typical treatment system, the neutralizing agent is hydrated and/or slurried (if necessary), then added to the influent water. A flocculent may be added to improve the settling characteristics of the sludge. The treated water is sent to a settling basin/clarifier/thickener to allow settling of the precipitates. Other separation processes, such as a ceramic micro-filtration system (CMS) or other filtration techniques, may be used for separation. Water is generally discharged from the top of the tank, and sludge discharged from the base. Sludges often have high water content that increases the cost of sludge handling and disposal. A filter

press can be used to increase the sludge solids content. Sludge solids content can also be increased significantly using the HDS process, where recycled sludge is mixed with the neutralizing agent prior to mixing with the influent water. Depending on effluent requirements, a polishing stage may be used in conjunction with precipitation. Oxidation of iron and/or manganese into forms that are more easily precipitated may be done either before or after addition of the neutralization agent.

#### 4.2.2 Ion Exchange

Ion exchange is the chemical process involving the reversible exchange of ions between a liquid and a solid. Ion exchange substrates, such as ion exchange resins and zeolites, can be used to remove unwanted ions from a liquid and substitute more acceptable ions, most commonly sodium, potassium, calcium, and chloride. The substrate is then regenerated, usually with a dilute acid. The regeneration solution and spent ion exchange substrate must be discarded. Total dissolved solids concentrations are not decreased in this process, but the composition of the dissolved solids is changed. Ion exchange works best on dilute solutions, and would probably be part of a polishing stage for high contaminant concentration waters. The cost of this process can be high.

#### 4.2.3 Oxidation

Oxidation can be used to precipitate iron and manganese oxides and can be used as pre-treatment to produce more readily precipitated forms of metals. Chemical oxidation uses oxidizing agents such as potassium permanganate, hydrogen peroxide, hypochlorites, chlorine, or chlorine dioxide. Aeration can also be used to facilitate oxidation. Oxidation can be inhibited by the pH drop associated with the formation of metal hydroxides. Oxidation alone is generally not effective in removing cadmium, copper, manganese, or zinc to concentrations below discharge criteria.

#### 4.2.4 Electrochemical Processes

An electric current is applied to electrodes submerged in the liquid solution and metals are deposited on the cathode or precipitate from solution. The precipitate sludge and the acid

solution used to periodically regenerate the electrodes must be disposed of. This process is most commonly used in gold production. In water treatment, it is most commonly used for the reduction and precipitation of hexavalent chromium, but can also be used to remove arsenic, cadmium, molybdenum, aluminum, zinc, and copper ions from water. Electrowinning and electrocoagulation are specific examples of electrochemical processes.

#### **4.3 BIOLOGICAL TREATMENT TECHNOLOGIES**

Biological treatment is based on reactions of organic substrate. The organisms may be used to directly or indirectly to treat the metals. Direct treatment is when a biological reaction with the organic substrate facilitates metal ion removal from the contaminated water. Indirect treatment is when the biological reaction is used to form products that remove metal ions from the contaminated water. For example, an indirect biological treatment may consist of a bioreactor used to convert sulfate to sulfide, allowing for precipitation of metal sulfides. BioteQ Environmental Technologies, Inc., of Vancouver, British Columbia, Canada, uses a patented sulfur reduction process that uses elemental sulfur and other reagents, including sulfur-reducing bacteria, to produce hydrogen sulfide which then reacts with AMD to precipitate metal sulfides. A clarifier is used to separate the precipitate from the treated water. Copper, zinc, nickel, and other metals can be selectively recovered from the sludge. This process is often used in conjunction with lime precipitation, and secondary treatment may be required. BioteQ also offers a patented sulfate reduction system that produces discharge water that meets extremely low metal and/or sulfate discharge requirements, but the cost of this process is much higher than the sulfur reduction process.

Organic substrates can be used as adsorption and ion exchange media as described above. Regeneration of organic substrates can be unpredictable and problematic in continuous flow situations.

#### **4.4 ACID MINE DRAINAGE WATER TREATMENT**

AMD is a common problem in the Western United States. Much effort has gone into the development of effective alternative and innovative treatment technologies to treat water contaminated with metals and to recover the metals. Ultimately, the result of large scale surveys of applicable technologies, bench-scale and pilot scale studies, and evaluation of operational constraints indicate that precipitation with subsequent solids settling is the preferred primary process for large scale metals removal from

AMD. Based on a survey of the remedies at Superfund sites within EPA Region 8 and particularly the state of Colorado, precipitation/neutralization with subsequent settling is a preferred alternative for AMD sites.

Within the realm of chemical precipitation processes, there are many variables that must be considered, including neutralization agent, process options (high density sludge process, multi-step precipitation), flocculent addition, water/precipitate separation, aeration, and sludge handling. Several process options have been developed to optimize neutralization/precipitation WTP systems. The HDS process has proven effective in reducing solids handling requirements, regulating process pH, and reducing lime requirement. The Yak Tunnel Mine Drainage Treatment Plant in Leadville, Colorado, has operated using the HDS process for 11 years and has proven effective in meeting discharge standards with very rare upset conditions and more efficient operations and maintenance than traditional lime neutralization processes. Operating results reported for the Yak Tunnel WTP indicate that the clarifier underflow has 32 percent solids with a total two-hour retention time and the filter press filter cake is in excess of 50 percent solids. Single pass sludge density at the site was reported at 6 percent solids. Many other AMD WTPs also use the HDS process. The HDS process was patented but is now available for common use. Several vendors are available to apply the technology. HDS may be applied in series with other technologies that may be used for pre-treatment or polishing prior to effluent discharge for situations with very strict discharge limitations. Given the anticipated discharge requirements at Gladstone, pre-treatment and polishing should not be required using the HDS process. Multi-step precipitation may be more effective than single-step precipitation depending on the discharge criteria. Based on anticipated discharge standards and the goal of a simple operation, multi-stage precipitation will not be considered further for the Gladstone WTP.

Three recent water treatment technology evaluations were performed for sites similar to Gladstone. The Final Report - Resource Recovery Project was prepared by MSE Technology Applications, Inc. to present the project undertaken to evaluate treatment technologies for metal contaminated water in the Berkeley Pit in Butte, Montana (MSE Technology Applications, Inc. 1998). The project was conducted over six years. The Berkeley Pit contains more than 20 billion gallons of contaminated water from surface water sources, uncontaminated groundwater sources, mine pool water, and tailings impoundment leakage. The study was performed to identify methods to best recover clean useable water and recover marketable metals and other mineral resources. More than 40 technology proposals were reviewed and 15 technologies were demonstrated. The Horseshoe Bend WTP, constructed in

2003, utilizes a two-stage lime HDS system. Two-stages were required to ensure adequate aluminum removal. If necessary, a polishing step may be added to ensure that the effluent meets discharge criteria.

More recently, the Final Focused Feasibility Study for the Gilt Edge Mine site in Lawrence County, South Dakota, was prepared by CDM (Camp, Dresser, McKee Federal Programs Corporation (CDM) 2001). It presents an evaluation of interim alternatives to treat the AMD resulting from mining activities at the site. The evaluation was based on overall protection of human health and the environment, compliance with applicable or relevant and appropriate requirements, long-term effectiveness and performance, reduction of toxicity, mobility or volume through treatment, short-term effectiveness, implementability, and present worth cost. The recommended alternatives are to convert an existing caustic neutralization/precipitation plant to a lime process plant or construct a new treatment facility using a proprietary metals coordination process. The metals coordination process would require extensive pilot scale testing. The results of pilot studies on the two processes indicated that due to cost, reduced total dissolved solids (TDS) concentration, higher percent solids in the sludge, and higher quality effluent with lower toxicity, the HDS system was selected (EPA 2002). The HDS WTP was constructed during 2002 and 2003. The sludge produced was expected to consist of 25 % solids and does not require dewatering, but a post-treatment filtration system or carbon dioxide addition system may be required to reduce aluminum concentrations to levels below discharge criteria.

The existing Summitville, Colorado, WTP has more than seven years of operating history using hydrated lime precipitation followed by settling and filter-pressing to dewater the resulting sludge. The WTP discharges water that reliably meets discharge criteria, clearly demonstrating that the hydrated lime precipitation process is effective and reliable. An evaluation of the existing plant conducted at the request of EPA and CDPHE indicated that if a new WTP is built at the site, the HDS process would reduce sludge disposal requirements, lime requirement, and be more reliable than the existing process. Initial steps were taken to design and construct a new water treatment plant at the site; however, at this time construction has not been undertaken because of budgetary constraints.



#### 4.5 ALTERNATIVE SELECTION

The processes presented above were evaluated for applicability to the site based on the following key factors:

- Effectiveness;
- Cost (Capital and Operations and Maintenance);
- Reliability;
- Minimized solids generation;
- Proven technology at sites with similar conditions (high altitude, harsh weather conditions, mine contaminated waters);
- Discharge criteria similar to former WTP standards;
- Residual alkalinity in effluent water to potentially neutralize Cement Creek at and downstream of the WTP point of discharge; and
- No preference for metal recovery.

Filtration and membrane processes are effective in producing a clean effluent stream, but leave a concentrate stream that must be treated, requiring an additional step in processing and potentially higher capital and O&M costs. Filter maintenance is also a concern. Sedimentation is an effective separation process that warrants further consideration. Due to the high concentration of TDS in the untreated water and the unproven ability to operate a carbon adsorption plant at a continuous flow rate of 1,000 gpm, carbon adsorption is not considered feasible as a primary water treatment process for this site. Evaporation would require extensive area and/or energy requirements and would remove the relatively clean effluent stream that is useful to dilute Cement Creek. Solvent extraction would be costly and inefficient for removal of metals and is not proven for the treatment of all metals found in AMD. Chemical precipitation is frequently used for treatment of mine contaminated waters and was retained for consideration. Ion exchange is more effective on dilute solutions and would be better used as a post-treatment process. Oxidation as a primary treatment process may cause precipitation of iron and manganese, but would not reduce most metal concentrations to reasonable discharge criteria. Oxidation may be used in conjunction with other processes. Electrochemical processes are more applicable to more concentrated process streams and can have high power requirements. Direct biological treatment, such as metal reduction and plant uptake in constructed wetlands or ponds, would often provide inconsistent performance given the conditions at Gladstone (cold to cool temperatures most of the year, short growing season, high volumes of water during spring runoff with

relatively little storage capacity, limited area for wetlands/ponds, and high metal concentrations) and would require large treatment cells at the anticipated flow rate. Biologic treatment cells installed downstream of an active WTP at Gladstone would, however, provide additional reduction in metal loading at CC48 and should be considered by ARSG.

Selection of a water treatment method for the Gladstone site requires consideration of site conditions, space, waste disposal, reliability, effectiveness, and relative cost. For the reasons stated above, a chemical precipitation system was determined to be the most applicable process for Gladstone water treatment at this time. Chemical precipitation is a proven water treatment method for metals contaminated waters.

Different types of chemical precipitation were considered, including active, passive, and semi-passive lime precipitation, hydroxide precipitation, and sulfide precipitation. Passive chemical precipitation treatment may be useful at sites with lower flow rates and metals concentrations but would not be effective in reliably reducing metals concentrations at A72. A semi-passive chemical precipitation treatment system with lime addition and mixing followed by discharge to settling ponds or a pond-like system was considered; however, based on the anticipated flow rates, the requirement for a relatively large pond system, and problems with a pond-only system during winter months when the impact of waters on downstream sources is highest indicates that this would not be preferred over a more reliable active chemical precipitation system. Active lime precipitation systems have proven reliable in removing metals from large quantities of water, even in harsh conditions as may be encountered at Gladstone. In order to meet the preference for a simple process with low sludge generation, an HDS lime precipitation systems was selected for use at the Gladstone site. This decision was presented by UOS and agreed to by ARSG prior to development of the WTP conceptual design and cost estimates.

## **5.0 GLADSTONE HDS WATER TREATMENT PLANT OPTIONS**

Many factors that may significantly affect development of the conceptual design/preliminary cost estimate for a water treatment plant for the Gladstone site were investigated as part of this study. Factors included: HDS process options, influent water chemistry, influent flow rates, and operating pH. These topics are discussed below, and parameters selected for the conceptual design and cost estimates are identified.

Selection of parameters for the conceptual design/cost estimate was partially based on flow rate measurements and water quality sampling conducted in July, September, and November 2005 (UOS 2006), and on treatability studies performed on water collected from three water sources during September 2005 (Canadian Environmental and Metallurgical, Inc. (CEMI) 2006). A summary of the data collection is provided in Section 5.2 to support the following sections.

## **5.1 PROCESS OPTIONS**

Several process options may be used in an HDS neutralization plant. The following sections describe various options and their applicability to the Gladstone WTP. While some options have been selected for the conceptual design and cost estimate provided in this report, the options selected here may be reconsidered prior to final plant design as indicated by site restrictions, an on-site pilot study, changing discharge criteria, cost, and other factors.

### **5.1.1 Neutralization Agents**

Many neutralization/precipitation agents can be used to precipitate metals from solution. Most produce one of three categories of precipitates: metal hydroxides, metal sulfides, and metal carbonates. Hydroxide precipitation is the most commonly used and is effective in meeting typical WTP discharge limits. Generally calcium oxide and calcium hydroxide have been shown to give faster reaction rates than magnesium oxide and magnesium hydroxide and both of those have faster reaction rates than calcium or magnesium carbonates. Magnesium oxides and hydroxides may produce precipitates with different settling characteristics than calcium oxides and hydroxides. Magnesium hydroxide is three times more expensive than calcium hydroxide on an equivalent neutralization basis and reacts more slowly with the metal ions, but less sludge may be formed and precipitate particle sizes may be larger and therefore settle more rapidly. The logistics of using magnesium hydroxide are more complex because it is delivered to a site in slurry form, must be agitated to keep the solids suspended, and requires special storage conditions. Magnesium hydroxide has a lower equilibrium pH than the other hydroxides and carbonates, therefore the upper end of the pH range (approaching 9.0 and above) would not be practical. This means that using manganese hydroxide may require a two-stage precipitation process, the second stage using a different precipitation agent, to meet current discharge criteria. Most other hydroxide precipitation agents are

primarily used when they are easily available at low cost from local sources, not because they are more effective than lime.

Sulfide precipitation uses one of several sulfide based reagents to form metal sulfides. Sulfide precipitation is not effective for precipitating manganese and has not been proven in long-term large-scale practice. As sulfide precipitation plants now in use are evaluated and the operation and efficiency of these plants is standardized, this type of precipitation process may become a more attractive alternative for Gladstone, particularly given the potential for metal recovery.

Carbonate precipitation can be used as a secondary treatment to remove calcium after hydroxide precipitation. It can be used to precipitate copper and zinc salts that are relatively insoluble in neutral to near-neutral water, but the reaction rates are slow, so carbonate precipitation is not generally used as a primary removal method.

To remove unwanted sulfate from solution, specific neutralization agents can be used to precipitate calcium sulfate ( $\text{CaSO}_4$ ), barium sulfate ( $\text{BaSO}_4$ ), lead sulfate ( $\text{PbSO}_4$ ), or jarosite ( $\text{KFe}_3(\text{SO}_4)_2(\text{OH})_6$ ). Since sulfate has not been identified as a contaminant of concern for the Gladstone site, these agents are not recommended at this time. Sulfate concentrations can also be reduced using the pH adjustments caused by hydroxide precipitation, but generally not to concentrations low enough to meet effluent standards.

Because of the proven success in large scale operations, preferable sludge settling characteristics, applicability to all metal contaminants of concern, and generally lower cost, cost estimates were performed based on using calcium oxide/hydroxide precipitation agents.

### 5.1.2 Flocculent

Flocculent addition is generally required in conventional precipitation WTPs and may be required in an HDS plant. A variety of flocculents is commercially available and have proven effective in treatment of water with similar contaminant concentrations. Pilot scale studies conducted prior to final WTP design should focus on flocculents used at the HDS plants with similar water conditions.

### 5.1.3 Water/Precipitate Separation

Precipitate must be removed from the treated water prior to discharge to Cement Creek. Separation is typically done using a clarifier/thickener and/or by filtration. The HDS process uses recycled sludge and aeration that increase the efficiency and effectiveness of gravity separation, so gravity separation was used for the conceptual design/cost estimate.

### 5.1.4 Pre- and Post-Treatment

The HDS process relies on the formation of co-precipitates with iron on the surfaces of recycled sludge particles to increase sludge density and stability. Oxidation of ferrous iron to ferric iron requires oxygen transfer into the solution, so oxidation was included in the conceptual design/cost estimate. Oxidation will also precipitate manganese.

A variety of polishing steps can be used to further remove metals from the treated water. Commonly used methods are ion exchange, membrane technologies, or filters. The use of a polishing step will depend on the effluent requirements. Most polishing stages, while reducing metal content in the effluent, may also reduce the residual alkalinity. Because the residual alkalinity from lime precipitation may be desired to increase the pH of Cement Creek downstream of the WTP, potentially resulting in additional metal precipitation in Cement Creek, a polishing step may be counter to the project goals. Unless the project goals are amended to reduce effluent metal concentration requirements or pilot scale tests indicate that effluent metal concentrations are not being met, a polishing step is not recommended.

### 5.1.5 Sludge Handling

Sludge produced during water treatment may require special handling prior to disposal. The HDS process is used to minimize sludge handling requirements, but other processes may be indicated based on the initial results of an HDS pilot scale study. Sludge handling options include the use of a filter press or other filtration process or the use of evaporation ponds. Since there may be a potential disposal cell nearby, it is not clear whether additional solids handling is required or would be cost-effective. A filter press was not included in the

conceptual design/cost estimate. CEMI indicated that a rough estimate for a filter press to further increase the solids content of the sludge would cost approximately \$200,000 and would require an additional operator for operation.

As an alternative, sludge drying beds may be installed at the site or at the disposal site to allow sludge dewatering. A truck could be purchased for the site or hired for disposal of solids. CDPHE has provided concurrence that if the waste passes the toxicity characteristic leaching procedure (TCLP) test (EPA Method 1311), it would be Bevill Amendment-exempt from hazardous waste regulations but would be subject to solid waste regulations. Based on tests performed on sludge generated at the former Gladstone treatment facility, the sludge is expected to pass the TCLP test. If the sludge is disposed at a municipal landfill, the sludge will be required to pass the paint filter test. The paint filter test determines whether "free" water is present in a solid waste. Additional drying of sludge removed from the clarifier may be necessary for it to pass the paint filter test.

## 5.2 2005 SAMPLING AND ANALYSIS SUMMARY

Flow rate and water quality data have been collected for many years in Cement Creek and the Animas River, and numerous USGS studies have been performed that produced this information over time; however, the relatively recent bulkheading of the American Tunnel may have resulted in significant flow and water quality modifications. The system may still not be in "steady state" so even evaluation of current conditions may not accurately predict future water treatment requirements. *Flow rate and water quality parameters in Cement Creek (CC18 and CC48), the Animas River (A72), and potential water sources for treatment should continue to be measured regularly until design and construction of a plant.*

Because of the lack of current information regarding the specific water sources identified for treatment by ARSG, UOS measured flow rates and collected water samples during July, September, and November 2005. Measuring/sampling points included Cement Creek, North Fork, American Tunnel, and discharges from the Upper Gold King 7<sup>th</sup> Level, Mogul, Grand Mogul, Red and Bonita, Lark, Joe and John, Silver Ledge, Black Hawk, Big Colorado, Gold Point, and Eveline mines. An attempt was made to find additional adit discharges that may provide significant input to the Upper Cement Creek system; however, no additional discrete discharges were observed. This does not mean that other

mines do not contribute to Cement Creek contamination, just that these other sources do not appear at one surface location that would be readily collectible for treatment. The results of these activities are provided in the Gladstone Treatment Plant Sampling Activities Report (UOS 2006). The results of the sampling were used to determine which waters should be sampled for bench-scale testing and considered for treatment to provide the most effective water system treatment. The results were also used to estimate reasonable flow rates and pH for use in the water treatment plant conceptual design and cost estimate.

Treatability studies were conducted by CEMI of Vancouver, British Columbia, Canada, to develop metal solubility curves for use in determining the optimum pH for metal removal and to provide preliminary lime utilization and sludge production rates for use in the conceptual engineering of the water treatment plant. The treatability studies were performed on water samples collected on September 21, 2005. Three water sources were evaluated:

- Sample 1 was a composite of four mine adit/tunnel discharge samples in proportion to their relative flow rates at the time of sampling: 19% from American Tunnel, 47% from Red and Bonita, 28% from Upper Gold King, and 6% from Mogul. These adits were selected for their high metals content and significant contribution to the Cement Creek metals load.
- Sample 2 was collected from upper Cement Creek just downstream of the American Tunnel inflow.
- Sample 3 was from the Silver Ledge adit discharge (the primary discrete adit that discharges to South Fork Cement Creek).

The results of the treatability study show effluent metal concentrations when water is treated to pH's of 7, 8, 8.5, 9, and 9.5. The results also indicate the amount of lime required to achieve the specified pH value. The treatability studies are presented in full in Chapter 2 of the CEMI Report (Appendix A) and are summarized where useful in the following sections.

### 5.3 WATER COLLECTION ALTERNATIVES EVALUATION

ARSG identified several Upper Cement Creek water sources known to contribute high loads of heavy metals to the Animas River watershed. Treatment of Cement Creek at Silverton was quickly eliminated due to the high cost of treating the entire volume of water at this location. Treatment of specific water sources near Gladstone was then considered. Discrete water sources included mine adits that discharge to Prospect Gulch, Dry Gulch, North Fork, South Fork, and Cement Creek above Gladstone. Treatment of Cement Creek at Gladstone was also considered. Flow measurement and sampling data from the 2005 sampling events described in Section 5.2 indicated very low relative metals contribution from adit discharges in Prospect Gulch and Dry Gulch. Because of the relatively low load reduction that would be realized and the additional infrastructure required to pump the water to the prospective WTP locations at Gladstone, treatment of these sources was eliminated from consideration.

The decision regarding which water sources to treat is based on a balance between cost, effectiveness, and metal load reduction. Load reduction estimates were calculated based on the July and September 2005 UOS sampling events because those are the only data collected from both Cement Creek at Gladstone and the mine adit discharges since installation of the bulkheads and discontinuation of water treatment. To determine the load reduction, the initial concentration of each metal was multiplied by the percent of the metal removed during the treatability study. For the purposes of this evaluation, a treatment pH of 9.0, typical for use in an HDS WTP, was used. The results shown in Table 4 indicate that in July, the metal load (excluding iron) contributed by the three adits/tunnel account for only 37 percent of the load at the Cement Creek sample location. In September, the adits/tunnel account for an average 80 percent of the metal load excluding iron. Iron was excluded from this comparison because calculations show a lower iron load at Cement Creek than contributed from the upstream adits, indicating that iron precipitates between the point of discharge from the adits and the Cement Creek sampling location. The relative load reduction from Cement Creek and the three adits/tunnel during spring flush, when metal concentrations in Cement Creek have been observed to be particularly high, cannot be determined at this time because current spring flush data is not available. The lack of spring flush data should not affect the flow rate and pH recommendations provided here because it is likely that for the water collection alternative of treating Upper Cement Creek water, the plant would not be designed for the peak spring flows because of cost restraints and practicality. The plant could be operated at 200 percent to 300 percent of the design capacity during



spring runoff to minimize metal loading to A72 during this period and/or a surge pond could be used to collect some of the metals-laden first flush waters.

**TABLE 4**  
**Load Reduction Summary**  
 (Load reduction in pounds per day by treating to pH 9.0)

	Three Adits/Tunnel		Cement Creek		Silver Ledge	
	July	September	July	September	July	September
Flow rate (gpm)	368	476	4,200	1,150	630	585
Aluminum	52	85	170	160	14	6.3
Cadmium	0.22	0.33	0.61	0.47	0.025	0.011
Copper	4.7	13	15	15	0.19	0
Iron	380	490	310	470	88	58
Manganese	55	160	0	180	4.4	3.8
Zinc	79	150	180	160	7.7	4.8
<b>TOTAL</b>	<b>570</b>	<b>900</b>	<b>680</b>	<b>990</b>	<b>110</b>	<b>73</b>

**TABLE 5**  
**Load Reduction per Volume of Water Treated**  
 (Load reduction in pounds per million gallons of water treated)

	Four Adits/Tunnel		Cement Creek		Silver Ledge	
	July	September	July	September	July	September
Aluminum	98	120	28	97	15	7.5
Cadmium	0.42	0.48	0.10	0.28	0.028	0.013
Copper	8.9	19	2.5	9.1	0.21	0
Iron	720	710	51	280	97	69
Manganese	100	230	0	110	4.9	4.5
Zinc	150	220	30	97	8.5	5.7
<b>TOTAL</b>	<b>1,100</b>	<b>1,300</b>	<b>110</b>	<b>600</b>	<b>130</b>	<b>87</b>

The load reductions presented in Table 4 were then divided by the flow rate to determine the metal load reduction per unit volume of water treated (Table 5). This was done as an initial step to take into consideration the efficiency of treating the different water sources. If efficiency were not a factor, the more water treated the better. However based on ARSG guidance, the objective is to remove loading of the six metals of concern for the lowest unit cost possible. This is balanced by the need to achieve the highest practical reduction in metals concentrations at A72.

Based on the two sampling events, the most efficient approach appears to be treating the three adit/tunnel discharges upstream of Gladstone. Treating upper Cement Creek requires more water to be treated for somewhat higher total metal load reduction but provides significantly lower load reduction per unit volume. Treating Silver Ledge adit water is far less efficient than treating Alternative 1 water and the metal load reduction per unit volume of water treated is low, so treating the Silver Ledge adit water along with water from the three adits/American tunnel was not included as a third option. Cost effectiveness should also be considered. Because the three adits/tunnel water is more acidic and concentrated, more neutralization agent will be required and more sludge produced per unit volume of water treated, somewhat reducing the cost-effectiveness advantage of the significantly higher load reduction per unit volume of water treated for the three adits/tunnel treatment alternative.

Grand Mogul could be included as a fifth adit discharge to be piped to the treatment plant; however, as the 2005 sampling events reconfirmed, Grand Mogul discharge is seasonal. UOS flow rate measurements during 2005 were 110 gpm in July and 0.5 gpm in September. Therefore, it doesn't appear to be cost-effective to add the additional infrastructure to treat this water source. This decision should be reevaluated if the flow conditions change over time because of the impact from bulkhead installations or other factors.

Based on the above information the two water sources selected for the primary cost estimates are:

- Water Collection Alternative 1 - Three adit/tunnel discharges (American Tunnel, Red and Bonita, Upper (7<sup>th</sup> Level) Gold King, and Mogul), and
- Water Collection Alternative 2 - Upper Cement Creek just downstream of the American Tunnel inflow but upstream of the South Fork confluence.

The characteristics of WTP influent water for each of the water collection alternatives was estimated from the water quality observed during the July and September sampling events (Table 6).

**TABLE 6**  
**Anticipated WTP Influent Water Quality**

	Water Collection Alternative 1		Water Collection Alternative 2	
	July 2005	September 2005	July 2005	September 2005
<b>Field Parameters</b>				
Flow rate (gpm)	370	480	4,200	1,150
pH (S.U.)	3.3	3.5	3.5	3.5
Temperature (°F)	8.6	10	9.8	9.8
Conductivity (mS/cm)	1.9	2.1	0.57	0.57
<b>Analyte (Concentrations in micrograms per liter (µg/L))</b>				
Aluminum	11,970	15,390	3,670	11,500
Cadmium	50	60	1,3.4	35.2
Copper	1,080	2,250	306	1,110
Iron	87,400	84,700	6,100	34,200
Lead	61	56	13.7	25.9
Manganese	30,900	46,300	5,650	20,400
Zinc	18,000	25,000	3,580	11,500

#### 5.4 INFLUENT FLOW RATE

Items to consider in selecting design flow rate for the two water collection alternatives:

- Cost (How much funding is available for water treatment?)
- Cost/benefit ratio (What is the cost/benefit ratio to treat additional water volume?)
- Treatment standards (How much water must be treated to meet the standards or the required load reduction?)
- Current and historic data (and how well the data represent current conditions). Very little data is available for the adit discharges and surface water since the second and third American Tunnel bulkheads were installed.
- Timing of high concentration flows (stream water and seasonally flowing adit discharges have high initial concentrations of metals but concentrations are much lower after the initial flush. If diluted, there may be less need to treat the maximum flow rates. However, if early spring

runoff metal concentrations are extremely high, it may be more important to treat a higher percentage of the early spring runoff.)

- What are the consequences of inadequate capacity to treat the entire flow from the adits? (Penalties for not meeting standards, fish kills, and/or other biological degradation.)
- Uncertainties about whether the mine pool is at steady state, or if the bulkheads installed may still be causing changes in the hydrogeology.

#### **5.4.1 Water Collection Alternative 1 - Discrete Adit Discharges**

Flow rates applicable to the discrete adit discharges should be estimated using recent long-term average adit discharge flow rates. Because adit flow rates have not been measured in recent years, and data collected prior to or soon after bulkhead installation would not necessarily reflect current or future conditions, data collected during two sampling events in 2005 were used to estimate an effective design flow rate.

Flow rates measured during July and September were significantly different for the Grand Mogul and Upper Gold King 7<sup>th</sup> Level adits. The flow rate variation in Grand Mogul adit discharge appears to be seasonal, decreasing after the spring flush, so the decrease in flow rate is not unexpected. Of particular interest is the increase from 42 gpm to 135 gpm in flow from the Upper Gold King 7<sup>th</sup> Level adit. The reason for the increase is not immediately apparent and should be monitored in preparation for actual Water Collection Alternative 1 treatment plant design work.

The total flow from the adits for the July and September sampling events was 368 gpm and 476 gpm, respectively. After consultation with ARSG, the WTP was conceptually designed using a flow rate of 500 gpm. The plant could be operated at a peak flow rate of 200 percent of this flow, or 1000 gpm during peak runoff or periods of increased adit flows. The design flow rate of 500 gpm would allow some additional capacity to treat some of the upper Cement Creek flow if it were later deemed necessary.

#### **5.4.2 Water Collection Alternative 2- Cement Creek**

Flow rate data from 1996 through 2002 are available for Cement Creek at Gladstone. This location was referred to as CC18 and was located above the current American Tunnel inflow into Cement Creek. The use of historic CC18 data may be inappropriate to anticipate future conditions because flow rates of upstream adit flows and seeps may have changed because of American Tunnel bulkhead installation or other remediation projects. For example, the Red and Bonita mine adit discharge has gone from almost no flow to more than 200 gpm since the bulkheads were installed. Despite this limitation, the historic data from CC18 were evaluated as one approach to determine an appropriate flow rate. The average low-flow rate was determined by averaging measurements taken during the months of September through April for the years 1996 through 2002. The average low-flow flow rate was 580 gpm. The actual flow rates varied from 83 gpm to 1,841 gpm. Flow rates measured during the months of May through August (high flow months) averaged 1,827 and ranged from 340 gpm to 14,396 gpm. The three highest values, 14,396 gpm, 5,654 gpm, and 5,350 gpm were from 1999.

Several approaches could be made to selecting a flow rate for treating Cement Creek water at Gladstone. A plant could be designed to accommodate a reasonable expected maximum flow (5,500 gpm). This would require a large capital investment and would leave excess capacity during average flow years and during low flow months, but would be the most effective alternative in reducing metal concentrations in Cement Creek year round. Conversely, the plant could be designed to treat a minimum flow or the average low flow. This approach would require significantly less investment, but may result in less metal load reduction at A72 during spring runoff.

Based on September and November 2005 flow rate measurements of 1,150 gpm and 1,122 gpm, respectively, and ARSG direction to use low-flow periods for design, the conceptual design/cost estimate was prepared using a nominal flow rate of 1,200 gpm. The rationale for relying on these two flow rate measurements rather than average values for 1996 through 2002 is 1) snowpack and runoff during the 2004-2005 season was significantly above average, which may result in the 2005 measured flow rates being somewhat conservative relative to "average" years; and 2) previous CC18 data are three years old and hydrogeological conditions are substantially different than they were in 2002, apparently

resulting in the significant flow rate increase at the Red and Bonita mine (5 gpm to 210 gpm) and possible flow rate increases at other nearby seeps.

The hydraulic components of the treatment system could be designed to accommodate higher flow rates to allow increased throughput during peak runoff. Based on the performance of other HDS treatment plants, a marginal decrease in solids separation efficiency would be expected at flow rates 200-300 percent of design capacities. If ARSG anticipates using the WTP at flow rates above the design capacity for limited time periods, further solids settling data should be collected to determine expected total suspended solids concentrations in discharge water versus process water retention times.

## 5.5 OPERATING pH

Several items must be considered when selecting the pH for WTP design. Once a plant is built, the actual operating pH may be fine-tuned to optimize metals reduction and/or limit lime usage to reduce lime and sludge disposal costs. In general, operating at higher pH allows more contaminant precipitation (except for aluminum), allowing stricter water treatment standards to be met, but lime addition and disposal costs are higher. Operation at lower pH requires less lime addition, but does not remove metals to the same low concentrations as higher pH. Manganese and zinc are the Gladstone contaminants of concern that require higher pH for precipitation. A72 has not exceeded the manganese standard in recent years; therefore, the manganese concentration in the treatment plant effluent may not be a major factor in optimizing the operating pH.

The CEMI treatability study (Appendix A) was performed on water collected during September 2005 to estimate treated water concentrations at various pH levels (Tables 7 and 8). The samples were collected during September to represent the low-flow conditions that occur most of the year and because the relative contributions of the various sources were unknown until after the July data was evaluated. Because discharge standards have not been assigned for the WTP, the treatability study results were compared to standards assigned for the previous water treatment plant at Gladstone, plus some general Colorado Table Value Standards (TVS) (Tables 1 through 3). For Water Collection Alternatives 1 and 2, pH 8.5 would be required to meet the previous Gladstone WTP zinc standard. The other metals would meet the previous Gladstone standards at pH 7. For Water Collection Alternatives 1 and 2, an operating pH of 8.5 and 7.0 respectively, would be required to meet the

chronic TVS for copper. For both alternatives, pH 8.5 would be required to meet the chronic TVS for cadmium and zinc. For Water Collection Alternatives 1, a pH above 9.5 would be required to meet the chronic TVS for manganese. For Water Collection Alternative 2, a pH of 9.5 would be required to meet the chronic TVS for manganese.

Based on the above considerations, UOS proposed a treatment pH of 9 for the conceptual design and cost estimate for each alternative and ARSG concurred. This value removes more than 95 percent of the metals of interest with the exception of manganese. Approximately 65 percent of the manganese is removed at pH 9. A benefit of treating to pH 9 compared to a lower pH is that water could be discharged with residual alkalinity, allowing precipitation of additional metals within Cement Creek. If it is later decided that the treatment plant will need to operate at a pH above 9.0, it will be a relatively simple calculation to determine the incremental lime and sludge disposal costs. Capital costs should not be affected significantly.

**TABLE 7**  
**Treatability Study Water Chemistry**  
**Water Collection Alternative 1 – Four Adits/American Tunnel (American Tunnel, Mogul, Red and Bonita, and Upper Gold King proportionate to September 2005 flow rates)**  
**(Concentrations in milligrams per liter (mg/L))**

	Influent Water	pH 7		pH 8		pH 8.5		pH 9		pH 9.5	
	Conc.	Conc.	% Reduction	Conc.	% Reduction	Conc.	% Reduction	Conc.	% Reduction	Conc.	% Reduction
Aluminum	19	0.066	99.6	0.11	99.4	0.29	98.4	0.47	97.5	1.2	93.4
Cadmium	0.066	0.032	51.5	0.016	75.6	0.0027	96.0	0.00076	98.9	<0.0005	>99.9
Copper	3.0	0.030	99.0	0.029	99.0	0.019	99.4	0.015	99.5	0.013	99.6
Iron	87	0.1	>99.9	0.1	99.9	0.1	99.9	0.1	99.9	0.1	>99.9
Manganese	53	45	14.4	38	28.4	21	60.7	18	65.3	3.0	94.4
Zinc	31	7.7	74.9	2.1	93.0	0.25	99.2	0.027	99.9	0.023	99.9

**TABLE 8**  
**Treatability Study Water Chemistry**  
**Water Collection Alternative 2 - Upper Cement Creek below American Tunnel Inflow**  
**(Concentrations in milligrams per liter)**

	Influent Water	pH 7		pH 8		pH 8.5		pH 9		pH 9.5	
	Conc.	Conc.	% Reduction	Conc.	% Reduction	Conc.	% Reduction	Conc.	% Reduction	Conc.	% Reduction
Aluminum	11	0.066	99.4	0.081	99.3	0.10	99.0	0.22	98.0	0.30	97.3
Cadmium	0.033	0.016	52.4	0.0096	70.6	0.0043	86.8	0.0012	96.3	0.0002	99.4
Copper	1.1	0.023	98.0	0.017	98.5	0.013	98.9	0.012	99.0	0.013	98.9
Iron	26	0.028	99.9	0.034	99.9	0.034	99.9	0.028	99.9	0.032	99.9
Manganese	21	19	8.2	19	10.2	17	17.3	7.2	65.0	2.3	89.0
Zinc	12	3.3	72.5	1.1	90.5	0.25	98.0	0.076	99.4	0.048	99.6

## 5.6 WTP LOCATION

Two potential locations have been identified for the WTP by ARSG, the Gladstone site and the Success Placer Site (Figures 3 and 4). Additional locations may be identified in the future. Selection of a site is dependent on property ownership, year-round accessibility, stability, location and elevation relative to influent water sources, available area, avalanche susceptibility, available infrastructure, and cost. Property ownership issues are being investigated by ARSG. The site must be accessible to plant operators, suppliers, and sludge disposal equipment year-round, possibly requiring road construction or improvements, avalanche mitigation, and snow removal. Prior to final site selection, a geotechnical analysis must be performed to ensure that the land is stable and can support the facility. The location relative to the influent water source will determine the extent of the structures required to get the water to the facility. If the facility is located upgradient of the water source, the water must be pumped to the facility prior to treatment, potentially a large expense. Seeps located between the Success Placer and Gladstone location would not be addressed for Water Collection Alternative 2 if Cement Creek water is collected upgradient of the Success Placer, one of the potential WTP locations. Right-of-way for piping source water to the WTP must be available. Any restrictions on the treated water discharge location should also be considered in selection of the WTP location. Additional property that may be available can be used for storage and can add to the efficiency of water treatment if a surge pond is added to normalize influent flow rates and water quality or if drying beds are installed for additional sludge dewatering prior to disposal. Costs associated with the location selection include snow removal, road improvements/construction, retaining wall, avalanche control, and utility improvements (telephone lines, power, water, sewer, etc.).



## 6.0 CONCEPTUAL DESIGN

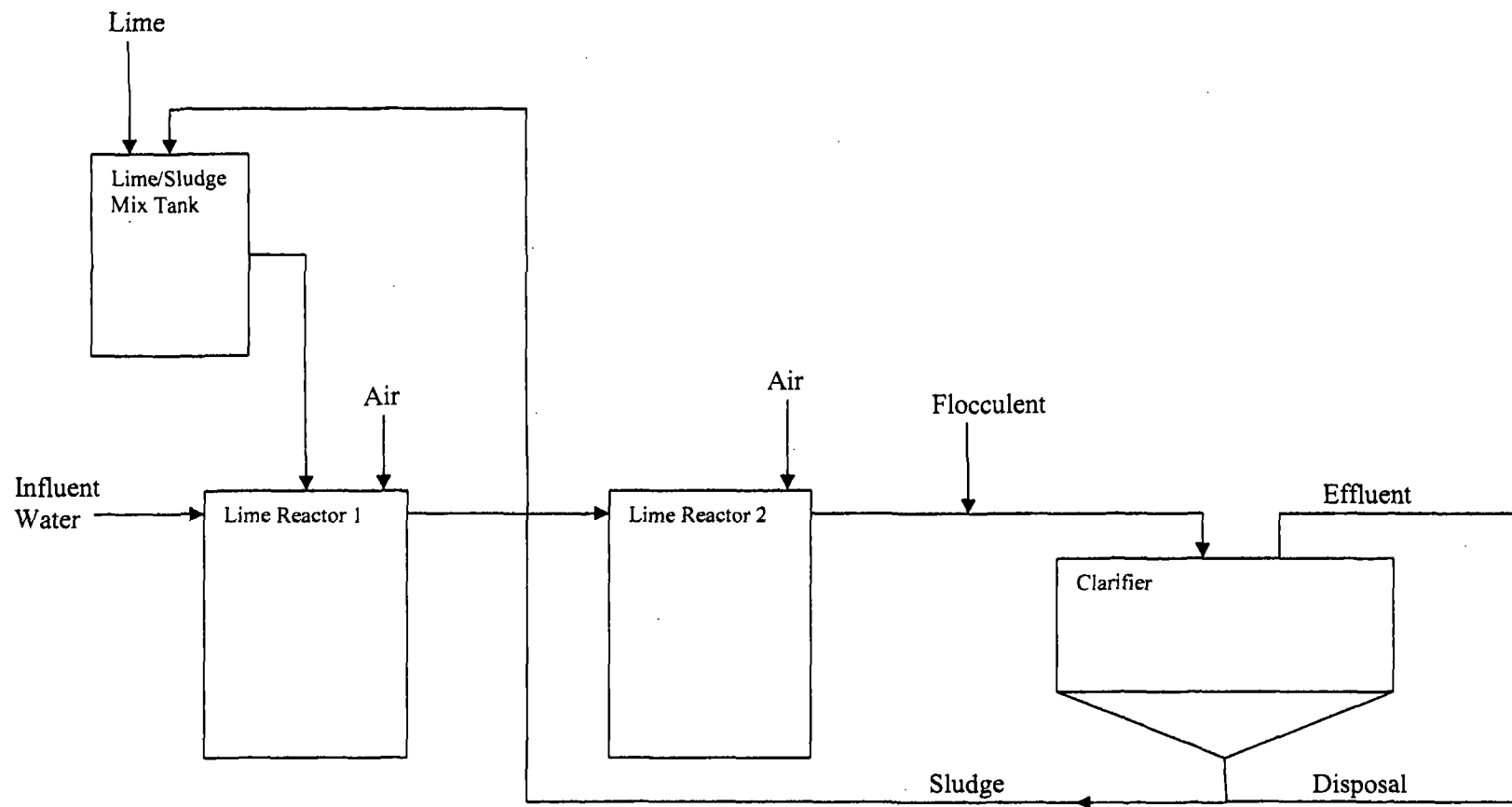
Two conceptual designs (one for Water Collection Alternative 1 and one for Water Collection Alternative 2) were developed for an HDS lime neutralization plant for the Gladstone site based on the chemistry determined through bench scale testing and options discussed in Section 5. Details regarding the designs are provided in the CEMI Report (Appendix A) and summarized here.

The figure below displays the components of the conceptual design. Equipment lists are provided in Appendix C of the CEMI Report.

Appendices D and E of the CEMI report show the detailed conceptual process flow sheet and the conceptual general arrangement plan used for the cost estimate. Lime and recycled sludge are combined in the lime-sludge mix tank and the resultant mixture functions as the neutralization agent. The mixture is added with metals laden influent water in Lime Reactors 1 and 2, where aggressive aeration and high shear agitation are used to obtain optimum process chemistry and sludge separation characteristics. As water flows from Lime Reactor 2 to the clarifier, flocculent is added to improve settling characteristics. Gravity separation and thickening occur in the clarifier where discharge water is decanted off the top, and sludge is removed from the bottom and either recycled or disposed. Additional sludge density may be obtained in subsequent settling ponds or by use of a filter press; however, those options were not included in the conceptual design and cost estimate.

HDS process modeling and cost estimation was performed for each of the water collection alternatives. Parameters used in the model include influent chemistry, flow rate, operating pH, sludge production, sludge recycle, air requirements, and lime consumption. Process design parameters are presented in the CEMI 2006 report (Appendix B1 for Water Collection Alternative 1 and Appendix B2 for Water Collection Alternative 2) and are summarized in Table 9.

## HDS Treatment Process Diagram



**TABLE 9**  
**Process Design Parameters**

Parameter	Water Collection Alternative 1	Water Collection Alternative 2
Normal Flow Rate	500 gallons/minute	1,200 gallons/minute
Maximum Flow Rate	1,000 gallons/minute	2,000 gallons/minute
Feed pH	2.4	3.3
Operating pH	9.0	9.0
Solids Generation	0.055 tons/hour	0.057 tons/hour
Maximum Solids Generation	0.109 tons/hour	0.095 tons/hour
Normal/Maximum Sludge Recycle	36:1	56:1
Percent Solids in Sludge	25 percent	25 percent
Residence Times		
Reactor Vessels	60 minutes	60 minutes
Lime-Sludge Mix Tank	4 minutes	4 minutes
Recycle Water Tank	10 minutes	10 minutes
Lime Slurry Tank Hold Time	24 hours	24 hours
Clarifier Upflow Ratio	1.10	1.10
Lime Requirement (CaO)	0.044 tons/hour	0.047 tons/hour
Lime Requirement (Ca(OH) <sub>2</sub> )	0.058 tons/hour	0.063 tons/hour
Flocculent Addition Rate	1 kilogram/hour	1 kilogram/hour
Flocculent Concentration	0.05 percent	0.05 percent
Oxygen Requirement	32 standard cubic feet/minute	32 standard cubic feet/minute
Clean Water for Flocculent Mixing	1 ton/hour	1.64 tons/hour

## 7.0 COST EVALUATION

The purpose of the cost evaluation section of this report is to identify a range of costs that may be associated with the construction and operation of an HDS water treatment plant. As with any complex project, especially one with many stakeholders involved, the development of a specific approach involves an iterative process with a series of proposals, evaluations, and adjustments to the proposals. This project is in the conceptualization stage -- many factors associated with this project have not been determined. Some of the project uncertainty is associated with technical considerations including water chemistry and flow rate and whether stringent discharge standards will apply. A typical target precision for costing of a conceptual project is  $\pm 30$  percent. However, because it is unknown whether many of the possible elements of a WTP envisioned in this report will ultimately be constructed, the precision of project costing presented in this report may not meet the typical standard.

Costs associated with construction and operation of a WTP at or near Gladstone were calculated and are tabulated here. WTP construction and O&M costs for both water collection alternatives were estimated by CEMI (Appendix A). Sludge transportation and disposal costs for two disposal options identified by ARSG were estimated by UOS. Additional site development costs associated with the WTP at the two potential sites identified by ARSG were estimated by UOS with assistance from a URS Corporation senior cost estimator. A summary of WTP construction costs, site development costs, and O&M costs are tabulated and present value costs calculated for each combination of the water collection alternatives, WTP sites, and sludge disposal options. The term scenario is adopted for the purposes of this report to indicate the eight combinations of water collection alternatives, site, and sludge disposal options as shown in Table 11. The conceptual physical layout for four possible combinations of water collection alternatives and WTP site are shown in Figures 3 through 6.

## **7.1 WTP CAPITAL AND OPERATION AND MAINTENANCE COSTS**

CEMI prepared WTP construction and O&M cost estimates for the two water collection alternatives. These estimates are the same regardless of the WTP location. The cost estimates were based on CEMI models that incorporate technical requirements with many years experience in the design and construction of HDS facilities. The CEMI costs have a precision of  $\pm 30$  percent. The capital cost estimates include the costs of the WTP building and major process equipment, but not site development, WTP design costs, or other indirect costs. The WTP building is estimated to require a footprint of 150 feet by 100 feet for both water collection alternatives. External costs for installations such as a surge pond, road improvements, or the water collection systems discussed below are not part of the CEMI estimate. The capital costs for Water Collection Alternatives 1 and 2 were estimated at \$3.5 million and \$4.8 million, respectively.

O&M costs include the costs for reagents required to treat the design flow, power, labor, and equipment maintenance. The CEMI O&M cost estimate does not include reagents to treat greater than the design flow (that may occur during spring runoff) or routine sampling and sample analysis. The labor cost is estimated assuming that the WTP will be highly automated and include telemetry that will enable an operator in Silverton to check plant status. However the actual anticipated labor cost should be evaluated carefully by ARSG based on the availability and cost of qualified personnel. Annual O&M costs for Water Collection Alternatives 1 and 2 were estimated at \$360,000 and \$440,000, respectively. In addition, annual technical and administrative support costs were estimated to cost \$30,000 per year for both water collection alternatives.

### **7.1.1 Use of Existing WTP Equipment**

A lime slaker and various tanks and ancillary equipment remain at Gladstone from the former treatment system operated until September 2004. At the time of this report, the equipment is owned by GKC and is located on San Juan Corporation property. It is assumed that this equipment will be available for use in a new WTP. The equipment is believed to have been operational at the time water treatment was discontinued and is of a similar capacity to that needed for either water collection alternative; however, the condition of the equipment has not been evaluated. For the purposes of this cost evaluation, it is assumed that the equipment has a net value of \$75,000.

### **7.1.2 Pre-Feasibility Study**

CEMI recommends a pre-feasibility study to confirm the budgetary estimates provided in their report. Costs may be further refined by performing an on-site pilot study (estimated cost of \$70,000), additional influent water flow and water quality measurements, and a seasonal profile.

A pilot study would identify water treatment effectiveness and parameters under typical site conditions. The approximate cost of a two- to three-week study is about \$70,000 and would assist in more accurate cost estimate and a more efficient design. Pilot scale tests would be performed on water similar to water that will generally be treated in the full-scale plant to avoid misleading results that could result in over- or under-design of the WTP. Of course, operating conditions at the site change seasonally and from year to year, so efforts to optimize plant efficiency are always ongoing. If the more concentrated Water Collection Alternative 1 water is used for pilot studies and plant design, the operating parameters may be able to be adjusted to treat Water Collection Alternative 2 water if that is required in the future.

Items that may merit evaluation in an HDS pilot scale study include:

- Neutralization agent;
- Sludge handling requirements;
- Sludge settling characteristics (for sizing clarifier);

- Oxygen addition rate (aeration requirements);
- Mixing requirements;
- Sludge recycle ratio;
- Lime addition rate;
- Flocculent type(s) and addition rate;
- Reaction rates;
- Recycle/lime mixing time; and
- Optimum operating pH.

Other parameters may also merit evaluation when more of the process requirements are determined. This study is considered an optional element and is included in the high-range cost estimates presented in Tables 11 through 13.

### **7.1.3 Treatment Plant Design**

Plant design may be approached in different ways depending on cost and comfort level with the selected design firm. Two approaches to plant design should be considered. A detailed design would provide specific engineering drawings for each and every portion of the WTP and is estimated to cost between \$400,000 and \$600,000. Alternatively, the plant could be field designed for a lower cost estimated at \$200,000. Specific components would be designated and ordered, and portions of the plant would be designed with specific engineering drawings. The components would be fabricated on site and support elements, such as piping and wiring, would be field fit during construction. This would significantly reduce design costs, but would require an experienced designer and construction personnel. The later approach would not include warranty from the design contractor. Obtaining detailed design documents from other EPA funded HDS plants may be useful for this option. For purposes of the net present value cost estimates, WTP design costs are estimated at \$200,000 for the low-range and \$500,000 for the high-range.

## **7.2 SLUDGE DISPOSAL COSTS**

ARSG requested that two sludge disposal alternatives be considered. The first involves hauling the sludge to the mouth of the canyon where it would be permanently placed in a yet-to-be-determined location. The second alternative involves transportation and disposal at the Bondad landfill located 16

miles south of Durango and a total of 73 miles from Gladstone. Costs were estimated for the four combinations of water treatment and disposal alternatives. The summarized costs are provided in Table 10. Disposal costs may be reduced by purchasing a vacuum or haul truck with which a WTP operator could haul the sludge.

**TABLE 10**  
**Sludge Transportation and Disposal Cost Estimates**

Disposal Option/Location	Water Collection Alternative	Sludge Volume (cy)	Transportation Cost (\$/cy)	Tipping Fee (\$/cy)	Total (\$)
Undetermined site near Silverton	Four adits/tunnel	1850	10.50	0	19,400
	Cement Creek	1940	10.50	0	20,400
Bondad Municipal Landfill	Four adits/tunnel	1850	34.40	16	93,200
	Cement Creek	1940	34.40	16	97,800

Assumptions: Sludge contains 25 percent solids and specific gravity of solids is 2.4  
 Each truck can haul 20 tons or 17.5 cubic yards of sludge per trip.

### 7.3 ADDITIONAL COSTS

A URS cost estimator prepared cost estimates for several additional components that may be necessary for the construction and operation of a WTP for this project. The costs were calculated separately for the two potential WTP locations identified by ARSG. The purpose of this portion of the cost evaluation is to assist ARSG in evaluating various project component options and in comparing project costs associated with two potential WTP sites. As with the WTP construction costs, these costs were estimated with a precision of  $\pm 30$  percent.

#### 7.3.1 Road Improvements

The Gladstone site is close (within 600 feet) to the county road, so minimum road improvements would be required. The Success Placer site is approximately 2,000 feet from the improved County Road, which is expected to need substantial improvements to facilitate truck passage required for lime delivery and operator vehicles during the entire year. The road may require widening in places and culvert installation may be required to allow proper road maintenance during wet conditions. Road improvement costs for the Gladstone and Success Placer sites were estimated at \$90,000 and \$240,000, respectively. Road

improvements were considered essential costs and are included in both the low-range and high-range costs presented in Tables 11 through 13.

### **7.3.2 Avalanche Control**

Reducing the likelihood of an avalanche in the area where one occurred at Gladstone during the winter of 2004-05 should be considered. Installation of six foot long steel sheet pile immediately below the road leading to the Upper Gold King 7<sup>th</sup> Level may reduce the potential for an avalanche to impact a WTP located at Gladstone or the access road leading to a WTP at the Success Placer. Conceptually, the sheet pile would be installed over a length of 100 feet and is estimated to cost \$80,000. Avalanche control is considered an optional element and is only included on the high-range cost estimates.

### **7.3.3 Retention Wall**

Currently the area available for locating a WTP at the Gladstone site is limited by BLM land ownership and by sloping terrain within the BLM-owned land. The removal of soil along the east side of the property and installation of a retention wall should be considered for the purposes of increasing the amount of buildable land surface available. For costing purposes, it was estimated that 10,000 cubic yards of soil would be excavated and that a retention wall measuring 200 feet by 20 feet would be installed. The soil excavating and retention wall construction is estimated to cost \$550,000. The retention wall is considered an optional element and is only included on the high-range cost estimates.

### **7.3.4 Utility Installation**

Phone and electrical service is currently available at Gladstone. It is anticipated that propane will be used to provide building heat. Extending the phone and electrical service to the Success Placer would require trenching and burying the service lines over an estimated 2,000 foot distance. Costs for this work are estimated at \$75,000 and \$290,000 for the Gladstone and Success Placer WTP locations, respectively. Utility installation was considered essential and costs are included in both the low-range and high-range costs presented in Tables 11 through 13.



### **7.3.5 Water Diversion from Cement Creek**

Water Collection Alternative 2 involves the diversion of 1,200 gpm of Cement Creek flow during normal operations. During spring runoff it may be desirable to divert as much as 3,000 gpm into the WTP. Construction of this diversion is estimated to cost \$200,000 for either the Gladstone or Success Placer WTP location. The diversion structure was considered essential and the costs are included in both the low-range and high-range costs presented in Tables 11 through 13.

### **7.3.6 Adit Piping**

The approach for conveying Water Collection Alternative 1 water to the WTP depends partly on the WTP location and on whether a surge pond is installed. This section presents the approach for piping adit/tunnel discharges to a WTP if a surge pond is installed. Additional piping costs may be required if a surge pond is installed.

For the Gladstone WTP location using Water Collection Alternative 1, the Mogul, Red and Bonita and Upper Gold King 7<sup>th</sup> Level adit discharge water would be collected, manifolded together, and a single pipe would be used to carry the water to Gladstone (Figure 3). The American Tunnel discharge would be piped directly to the WTP. For the Success Placer WTP location using Water Collection Alternative 1, water would be piped from the Mogul, Red and Bonita and Upper Gold King 7<sup>th</sup> Level adit discharges to the WTP, and water from the American Tunnel would be pumped to the WTP (Figure 5).

For Water Collection Alternative 2, water would be collected directly from Cement Creek for the Gladstone WTP location (Figure 4), but because the American Tunnel enters Cement Creek downstream of the Success Placer location, the American Tunnel discharge would be collected and pumped to a Success Placer WTP (Figure 8).

For the Success Placer WTP location for the purposes of this cost evaluation, it is assumed that the following pipe sizes are adequate: Mogul – 3" diameter; Red and Bonita – 8" diameter; Gold King 7<sup>th</sup> Level – 6" diameter; and the combined flow to Gladstone – 10" diameter (Figure 3). Pipe sizes should be re-evaluated if more adit flow rate data are collected in the future. Some project participants stated that water was piped from an adit to the former

treatment facility at Gladstone and proposed that piping should not require burying to be functional year-round. Buried piping offers the advantage of stability, protection from weather, and disturbance by vehicles or animals. Unburied piping may be easier to access in the event of an obstruction. The low-range cost estimate assumes that none of the piping would be buried and the high-range estimate assumes that the pipe is buried at a cost of \$15 per foot. The cost of adit/tunnel piping varies from \$74,000 to \$109,000, depending on the scenario. The adit/tunnel piping was considered essential and the costs are included in both the low-range and high-range costs presented in Tables 11 through 13. The cost to bury the adit piping ranges between \$90,000 and \$169,500 and is only included in the high-range cost estimate.

### 7.3.7 Surge Pond

In the event that discharge standards apply to the treatment plant, a surge pond may be necessary to contain treatment water during WTP upset conditions. A surge pond could be constructed such that during WTP upset conditions, water would be retained for as many as 48 hours while repairs are being made. The surge pond could also be used for storage of water during the initial spring flush or other periods when metal concentrations are high. For purposes of this cost estimate, the surge pond was located on the Success Placer site for both potential WTP locations. Based on the two design flow rates, the surge pond volume for Water Collection Alternatives 1 and 2 would be 1,400,000 and 3,500,000 gallons, respectively. For scenarios 5 and 6 the surge pond was sized assuming that only adit and tunnel discharge water would be directed to the surge pond during upset conditions.

The water collection system that would be required with a surge pond at the Success Placer would depend on the water collection alternative and WTP location. The configurations used for the cost estimates are presented here. For the Gladstone location using Water Collection Alternative 1, the adit discharges would be piped to the surge pond and from the surge pond to the WTP. During normal operations, the water from the surge pond would flow directly to the WTP; during upset conditions, a headgate would be closed to retain treatment water in the surge pond. For the Gladstone location using Water Collection Alternative 2 Cement Creek would be diverted at Gladstone during normal operations. During upset conditions, water discharged from the Mogul, Red and Bonita, and Upper Gold King 7<sup>th</sup> Level adits would be piped to the surge pond and water discharged from the American Tunnel would be pumped to

the surge pond. This configuration was selected for the cost estimate because the Red and Bonita and Upper Gold King flow enters Cement Creek downstream of the diversion and would not be retained by the surge pond if not piped directly. For the Success Placer location using either alternative 1 or 2, the water collection system would be the same as without a surge pond except the water would be collected in the surge pond, then piped to the WTP for treatment.

Construction costs estimated for the surge pond were \$260,000 and \$390,000 for Water Collection Alternatives 1 and 2, respectively, and are included in the high-range cost estimates.

### **7.3.8 Construction Management for Site Development**

Construction management for auxiliary components (management of construction of elements not included in the CEMI estimate), including project preplanning, scoping meetings with the stakeholders, administrative support, and field supervision of construction activities, was estimated to range from 15 to 30 percent of site development costs. The construction management costs will depend on the specific elements that are actually included in the project. Construction management costs for essential elements were included in the low-range cost estimate and the construction management costs for essential and optional components were included in the high-range cost estimate.

### **7.3.9 Pumping American Tunnel Discharge to the Success Placer WTP Location**

In order to treat the American Tunnel discharge at the Success Placer WTP location using either water collection alternative, it will be necessary to pump the water approximately 2,500 feet with an increase in elevation of 165 feet. Costs to pump this flow of water assumed at 100 gpm continuously are estimated at \$10,000/year.

### **7.3.10 Fresh Water Supply**

An adequate source of fresh water from Minnehaha Creek is currently installed at Gladstone. It is assumed that this supply will continue to be available for a WTP location at Gladstone. For a WTP location at Success Placer, a fresh water source is needed to hydrate the lime.

Water coming from the Gold Point Mine appeared to be of good quality based on a sample collected in September 2005. It is unknown whether this water is available for use or meets the water quality requirements for flocculent mixing; however, for the purposes of this report it is assumed that this water supply is available and adequate. A closer source of fresh water may be identified that could reduce this cost estimate. Fresh water supply capital costs were estimated at \$25,000 for the Success Placer scenario cost estimates. For the low-range cost estimate, it is assumed that the pipe would not be buried. For the high-range cost estimate it is assumed that the pipe would be buried in the same trench as the Mogul adit flow pipe.

#### **7.3.11 Snow Removal**

It is assumed that snow removal for the County Road to Gladstone is provided without cost to the project. However, for the access road from Gladstone to the Success Placer, it is assumed that snow removal costs would be borne by the project. For the purposes of both the low-range and high-range cost estimates, it is assumed for that snow removal will be necessary for a period of five months each year and cost \$46,000/year.

### **7.4 NET PRESENT VALUE COSTS**

Capital and annual costs were calculated for each combination of water collection alternative, sludge disposal option, and WTP location (Tables 11 and 12). NPV costs calculations were performed using a discount rate of eight percent per year, an inflation rate of four percent per year, and a 20-year plant life. The low-range estimates for each scenario exclude the optional site development costs, while the high-range cost estimates include all of the optional site development costs discussed in Section 7.3. A summary of the NPV costs is presented in Table 13.

The results show that overall project costs are most sensitive to the water collection alternative selected. The NPV costs for Water Collection Alternative 1 are approximately \$2.5 million lower than for Water Collection Alternative 2 given the same WTP location and sludge disposal options. NPV project costs are nearly equally sensitive to the WTP location and the sludge disposal option. The Success Placer WTP location adds from \$600,000 to \$1.4 million to project costs compared to the comparable scenario using the Gladstone WTP location. The Bondad sludge disposal option adds approximately \$1.0 million to project costs over 20 years compared to the comparable scenario using a yet-to-be-identified location near Silverton.

**TABLE 11**  
**HDS Water Treatment Plant**  
**Capital Costs**  
 (Low Range Costs are unshaded; High range costs are shaded.)

Scenario	Water Collection Alternative	WTP Location	Sludge Disposal Option	WTP Design	WTP Capital	Credit for Existing Equipment	Other Site Development Costs	Total Capital Cost
1	Adits/Tunnel	Gladstone	Near Silverton	200,000	3,500,000	75,000	630,000	4,255,000
				570,000	3,500,000	75,000	2,220,000	6,215,000
2	Adits/Tunnel	Gladstone	Bondad Landfill	200,000	3,500,000	75,000	630,000	4,255,000
				570,000	3,500,000	75,000	2,220,000	6,215,000
3	Adits/Tunnel	Success Placer	Near Silverton	200,000	3,500,000	75,000	1,160,000	4,785,000
				570,000	3,500,000	75,000	2,200,000	6,195,000
4	Adits/Tunnel	Success Placer	Bondad Landfill	200,000	3,500,000	75,000	1,160,000	4,785,000
				570,000	3,500,000	75,000	2,200,000	6,195,000
5	Cement Creek	Gladstone	Near Silverton	200,000	4,800,000	75,000	830,000	5,755,000
				570,000	4,800,000	75,000	2,480,000	7,775,000
6	Cement Creek	Gladstone	Bondad Landfill	200,000	4,800,000	75,000	830,000	5,755,000
				570,000	4,800,000	75,000	2,480,000	7,775,000
7	Cement Creek	Success Placer	Near Silverton	200,000	4,800,000	75,000	1,400,000	6,325,000
				570,000	4,800,000	75,000	2,350,000	7,645,000
8	Cement Creek	Success Placer	Bondad Landfill	200,000	4,800,000	75,000	1,400,000	6,325,000
				570,000	4,800,000	75,000	2,350,000	7,645,000

**TABLE 12**  
**HDS Water Treatment Plant**  
**Annual Costs**

Scenario	Water Collection Alternative	WTP Location	Sludge Disposal Option	WTP O&M	Sludge T&D	Annual Snow Removal	American Tunnel Flow Pumping	Annual Project Management	Total Annual Costs
1	Adits/Tunnel	Gladstone	Near Silverton	360,000	19,000	0	0	30,000	409,000
2	Adits/Tunnel	Gladstone	Bondad Landfill	360,000	97,000	0	0	30,000	487,000
3	Adits/Tunnel	Success Placer	Near Silverton	360,000	19,000	46,000	10,000	30,000	465,000
4	Adits/Tunnel	Success Placer	Bondad Landfill	360,000	97,000	46,000	10,000	30,000	543,000
5	Cement Creek	Gladstone	Near Silverton	440,000	20,000	0	0	30,000	490,000
6	Cement Creek	Gladstone	Bondad Landfill	440,000	100,000	0	0	30,000	570,000
7	Cement Creek	Success Placer	Near Silverton	440,000	20,000	46,000	10,000	30,000	546,000
8	Cement Creek	Success Placer	Bondad Landfill	440,000	100,000	46,000	10,000	30,000	626,000

O&M      Operation and Maintenance  
 T&D      Transportation and Disposal

**TABLE 13**  
**Summary of Net Present Value Capital and O&M Costs**

Scenario	Water Collection Alternative	WTP Location	Sludge Disposal Option	Low-Range Cost Estimate	High-Range Cost Estimate
1	Adits/Tunnel	Gladstone	Near Silverton	\$9,700,000	\$11,600,000
2	Adits/Tunnel	Gladstone	Bondad Landfill	\$10,700,000	\$12,700,000
3	Adits/Tunnel	Success Placer	Near Silverton	\$10,900,000	\$12,400,000
4	Adits/Tunnel	Success Placer	Bondad Landfill	\$12,000,000	\$13,400,000
5	Cement Creek	Gladstone	Near Silverton	\$12,200,000	\$14,300,000
6	Cement Creek	Gladstone	Bondad Landfill	\$13,300,000	\$15,300,000
7	Cement Creek	Success Placer	Near Silverton	\$13,600,000	\$14,900,000
8	Cement Creek	Success Placer	Bondad Landfill	\$14,600,000	\$15,900,000

## 8.0 NEXT STEPS

Many of the parameters used to develop the cost estimates must be refined and/or confirmed to ensure that a plant is designed for reliable, efficient, cost-effective water treatment that meets the project goals. The following steps should be considered prior to construction of a water treatment plant at Gladstone:

- Continue evaluation of influent water source flow rates and quality. As mentioned above, flow rate and water quality parameters should continue to be measured regularly, at least quarterly, until a WTP has been designed and constructed.
- Continue evaluation of impact of treatment at CC48 and A72.
- Perform other studies to determine anticipated future flows and water quality, for example conduct a mine pool hydrologic study to determine any uncertainty about bulkhead installation.
- Select an influent water collection alternative (four adits/American Tunnel, Cement Creek, or other)

- Identify additional sites on which to construct the WTP.
- Perform geotechnical assessment at potential sites to determine suitability of the site for a WTP.
- Continue investigation of plant ownership/responsibilities.
- Pilot Study
- Plant Design
- Construction

It is important to perform regular water flow measurements and sampling of Cement Creek at Gladstone and/or the mine discharges identified for collection and treatment. Current flow measurement and water quality data are essential because historic flow and water quality information is limited and because the bulkheads placed in the American Tunnel may have significantly changed the site hydrogeology. Future flow and water quality predictions may require an analysis of current mine pool and surface water hydrology.

Additional potential site locations should be identified with consideration for plant location relative to the location of the influent water source (Cement Creek or the discrete mine adits), roads, utilities, available area, avalanche susceptibility, and other considerations. One or more of the locations should undergo a geotechnical evaluation to determine suitability for WTP construction prior to final selection of a site.

As discussed above, a pilot study would provide valuable information that could better focus WTP design efforts.



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**GLADSTONE WATER TREATMENT PLANT  
SAN JUAN COUNTY, COLORADO**  
FIGURE 1: Site Location Map

July 2006

UOS - START 3  
TDD No. 0509-41

▲ USGS Gaging Stations

1:45,000

0 0.25 0.5 1  
Miles

Source: NAIP 1 meter Aerial Imagery, 2005.  
<http://waterdata.usgs.gov/nwis>





**TARGET SHEET**  
EPA REGION VIII  
**SUPERFUND DOCUMENT MANAGEMENT SYSTEM**

DOCUMENT NUMBER: 1185361

SITE NAME: UPPER ANIMAS MINING DISTRICT

DOCUMENT DATE: 09/14/2006

**DOCUMENT NOT SCANNED**

Due to one of the following reasons:

- ☐ PHOTOGRAPHS
- ☐ 3-DIMENSIONAL
- ☒ OVERSIZED
- ☐ AUDIO/VISUAL
- ☐ PERMANENTLY BOUND DOCUMENTS
- ☐ POOR LEGIBILITY
- ☐ OTHER
- ☐ NOT AVAILABLE
- ☐ TYPES OF DOCUMENTS NOT TO BE SCANNED  
(Data Packages, Data Validation, Sampling Data, CBI, Chain of Custody)

DOCUMENT DESCRIPTION:

FIGURE 2: SITE AND SAMPLE LOCATION MAP

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_











**Legend**

- ✕ Mine
- ▨ Surge Pond
- Treatment Building
- Adit Pipeline
- Retaining Wall
- Avalanche Control
- Cement Creek Diversion
- Discharge
- Streams
- Potential Water Treatment Area



**GLADSTONE WATER TREATMENT PLANT  
SAN JUAN COUNTY, COLORADO**

FIGURE 4: Gladstone WTP Location -  
Cement Creek Water Collection


July 2006

UOS - START 3  
TDD No. 0509-41

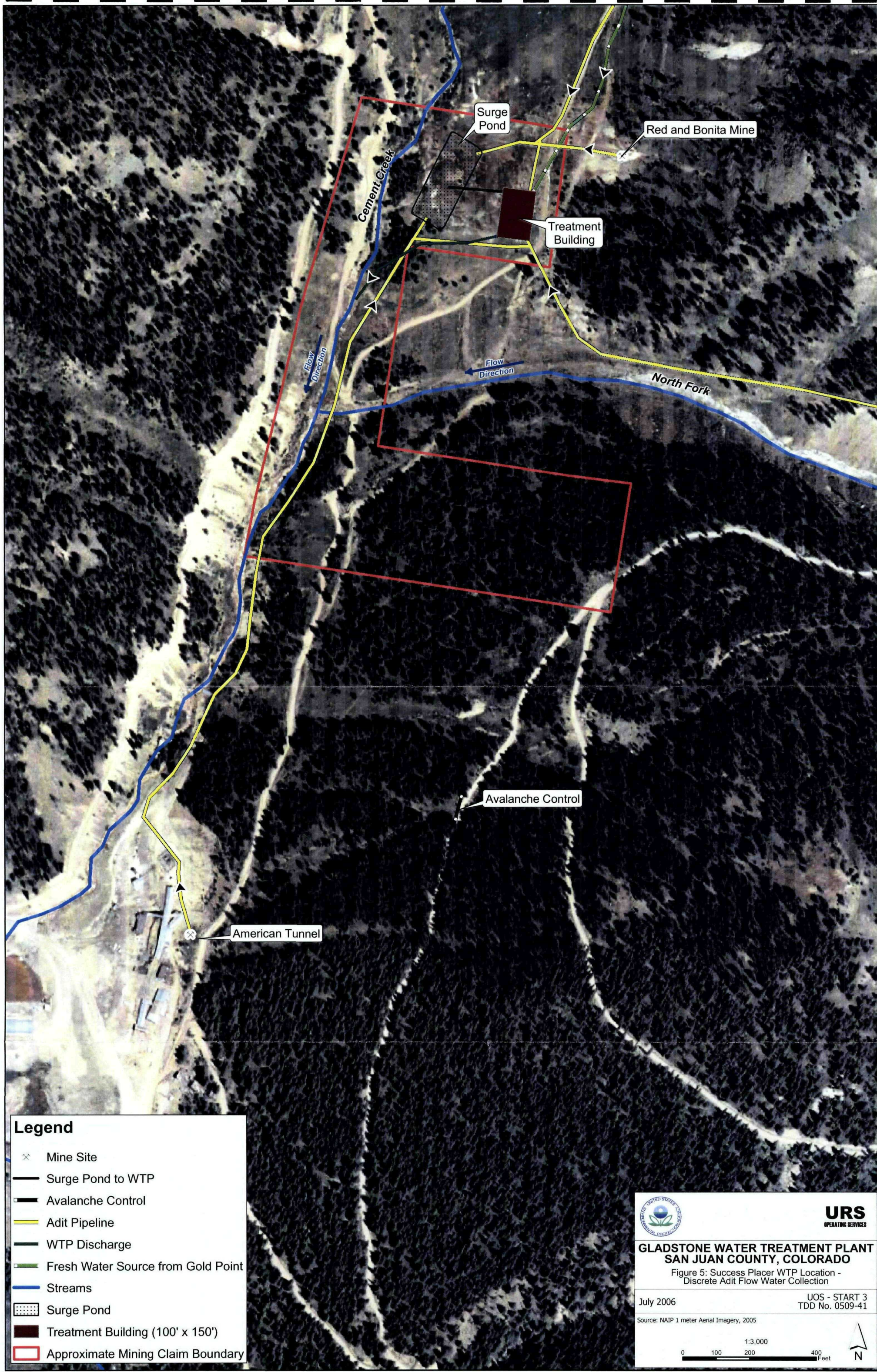
Source: NAIP 1 meter Aerial Imagery, 2005


1:3,000

0 50 100 200 Feet









**URS**

OPERATING SERVICES

**GLADSTONE WATER TREATMENT PLANT**

**SAN JUAN COUNTY, COLORADO**

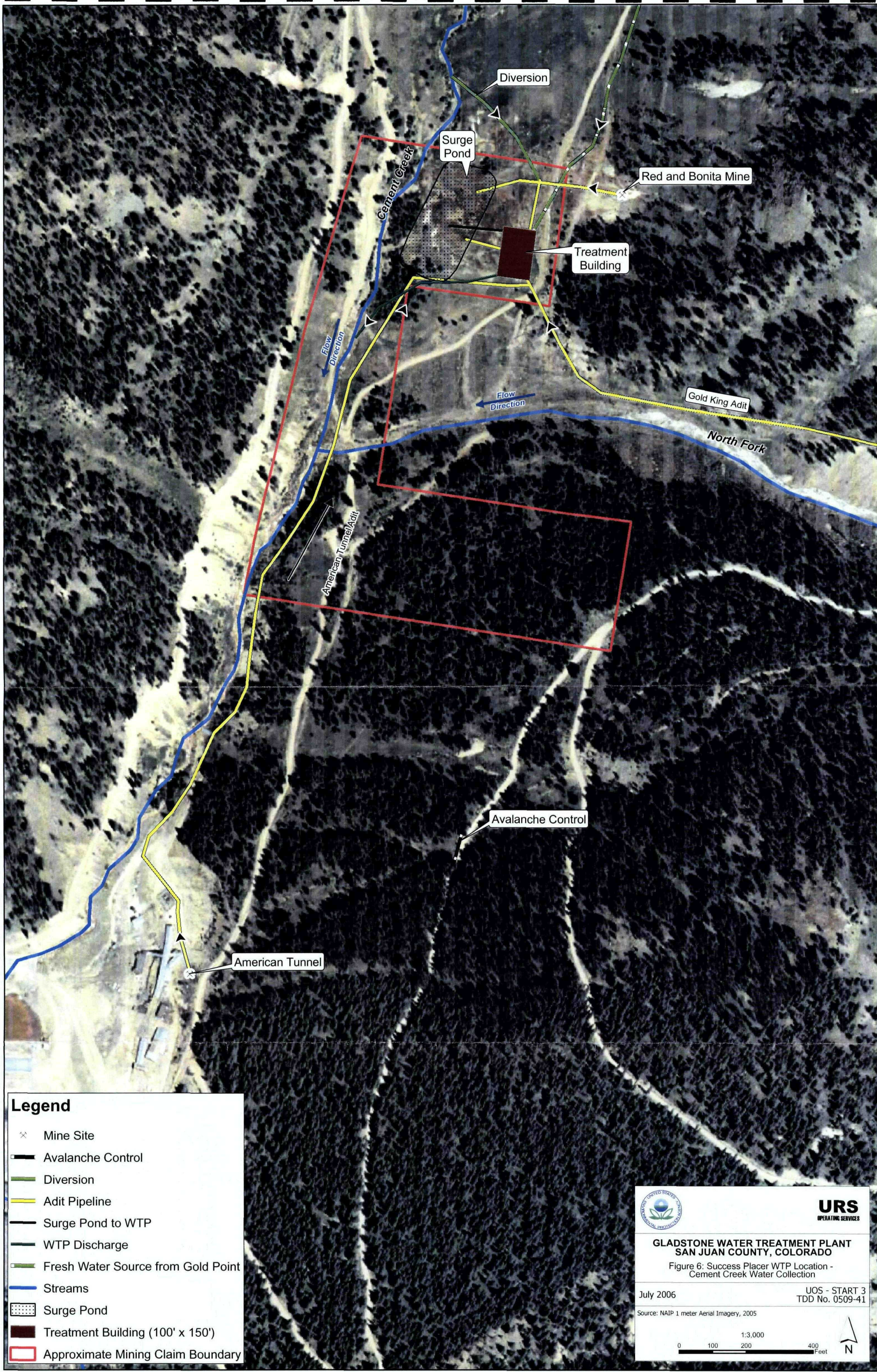
Figure 5: Success Placer WTP Location - Discrete Adit Flow Water Collection

July 2006

UOS - START 3  
TDD No. 0509-41

Source: NAIP 1 meter Aerial Imagery, 2005





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**GLADSTONE WATER TREATMENT PLANT  
SAN JUAN COUNTY, COLORADO**

Figure 6: Success Placer WTP Location -  
Cement Creek Water Collection

July 2006

UOS - START 3  
TDD No. 0509-41

Source: NAIP 1 meter Aerial Imagery, 2005

1:3,000  
0 100 200 400 Feet





## **APPENDIX A**

### **Gladstone Water Treatment Plant Conceptual Design**

**URS OPERATING SERVICES INC.**

**GLADSTONE SITE  
WATER TREATMENT PLANT  
CONCEPTUAL DESIGN**

**April 2006**



**6927 ANTRIM AVE.  
BURNABY, BC V5J 4M5  
CANADA**

## EXECUTIVE SUMMARY

CEMI was tasked to provide a conceptual design for a water treatment plant (WTP) at Gladstone, Colorado, complete with process flowsheet, mass balances and general plant layout. Two conceptual designs were developed based on the chemistry determined through bench scale testing and flowrates provided by UOS.

Three water sources were provided by UOS for bench scale neutralization treatment at five pH levels each in order to determine the optimal pH for metals removal. The first water sample was lower pH water with higher metal concentration collected from several discrete mine discharge locations that would be piped down gradient to the WTP. The second water sample was collected from Cement Creek, located adjacent to the probable WTP site and contained lower metal concentration and was at higher pH. The third water sample was collected from the Silver Ledge Mine (South Fork of Cement Creek) and had different water chemistry than the first two samples. Based on the test results, metals of concern can be treated to below reasonable discharge criteria using the HDS process at the operating pH of 9.0.

The water treatment plant for Sample 1 is designed to treat a flow of 500 gallons per minute (gpm) for normal operating conditions and the treatment plant for Sample 2 is designed to treat a flow of 1200 gpm for normal operating conditions. The operating pH for the plant was determined to be 9.0 as per UOS, and the results from the neutralization tests were used to determine the input parameters for the treatment plant design.

This study provides a conceptual HDS treatment plant design with operating cost estimates based on the recent water quality modelling. The scope of work for this study was to:

- Develop two process designs and process flowsheets based on the parameters provided by UOS
- Provide HDS process description

- Provide major equipment sizing and operating cost estimates

The yearly sludge production at 25% solids was estimated to be approximately 2115 tons (1917 tonnes) for Sample 1 treatment plant operating at 500 gpm and 2195 tons (1991 tonnes) for Sample 2 treatment plant operating at 1200 gpm. The air requirements (54 m<sup>3</sup>/hr at standard conditions for Sample 1 treatment and 46 m<sup>3</sup>/hr for Sample 2 treatment) were calculated with the assumption that all of the iron will be present in the ferrous form, and the oxygen transfer efficiency from air was assumed to be 20%.

The effluent water quality is expected to be as presented in Table 3-3 and Table 3-4 based on the laboratory testing. Operating a plant at pH 9.0 should produce an effluent that would meet reasonable discharge limits for all metals of concern.

The capital and operating cost estimates for water treatment plant are based on average flows provided by UOS. Process flowsheets have been developed to provide capital and operating cost estimates for both designs. The capital and operating costs for the water treatment plants are estimated with +/- 30% accuracy. The capital cost of the water treatment plant treating 500 gpm is estimated at **US\$ 3.5 million** and **US\$ 4.8 million** for a plant capable of treating 1200 gpm, direct plant costs only. Direct cost does not include process consulting, engineering costs, and taxes. Depending on the level of detail design and engineering, the engineering costs can vary in the range of 7500 to 10000 man-hours which may cost between US\$750,000 to US\$1,000,000. Cost of surge ponds, collection ditches, sludge ponds, owner's costs, etc. are not included in the capital cost estimates. The operating cost of the water treatment plant is estimated at **US\$ 364,290** per year for a Sample 1 treatment plant and **US\$ 437,111** per year for a Sample 2 treatment plant.

The cost estimates are preliminary based on CEMI's most recent experience in budgeting treatment and operating costs. A pre-feasibility study should be conducted to confirm the budgetary estimates provided in this study.

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## 1.0 INTRODUCTION

As part of an effort to identify options for construction of a new water treatment plant (WTP) at the Gladstone site, San Juan County, Colorado, URS Operating Services Inc. (UOS), the U.S. Environmental Protection Agency (EPA) Region VIII Superfund Technical Assessment and Response Team 3 (START3) contractor, tasked Canadian Environmental and Metallurgical Inc. (CEMI) to provide a conceptual design for a High Density Sludge (HDS) plant. Bench scale neutralization tests were conducted to determine the effectiveness of the HDS process to meet reasonable effluent standards and to determine effluent chemistry. The bench scale neutralization tests were conducted on three water samples collected from different locations and representing different chemistries. The process design and cost estimates provided in this report were based on the results of the bench scale treatability tests and design criteria provided by UOS.

### 1.1 *Advantages of the HDS Process*

The HDS process has many advantages over other lime precipitation systems. The most important of these is a substantial reduction in sludge volume resulting from an increase in sludge density. An increase from 2% solids to 30% solids is typical of HDS systems; this reduces the volume of sludge produced by over 95%. The resulting reduction in sludge disposal costs increases the cost effectiveness of the process. In addition to reduced sludge volume and superior sludge density, there is an increase in sludge stability, both chemically and physically. Within a few days of deposition, the sludge can drain to in excess of 50% solids and possesses enough physical stability to support the heavy equipment on the surface of the impoundment area. The sludge produced by a HDS process can be co-deposited with tailings. Chemically the sludge has shown excellent stability characteristics at mining sites in BC, Canada and at other sites. Following twenty-five years of impoundment at one facility, there has been no contamination of the surrounding groundwater or any other evidence of metal reversion.



Other advantages of the HDS process include:

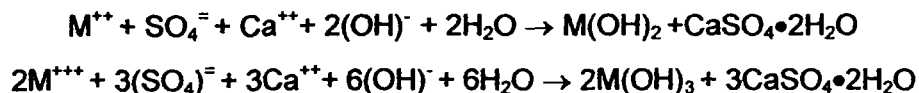
- A high quality effluent is produced,
- The process is easily automated,
- HDS is a proven technology, and
- Operating plants consist of standard equipment available from many competitive manufactures, which reduces the need for large spare parts inventories,
- Lower neutralization costs than conventional lime treatment.

## 1.2 The HDS Process

The effective removal of base metals in a chemically stable form in the HDS process is primarily the result of the formation of co-precipitates with iron on the surfaces of the recycled sludge particles. The chemical stability of the precipitates is favorably influenced by a high iron to total metals ratio in the treatment plant feed. In all cases, the oxidation of ferrous iron to ferric iron is the principal oxygen-consuming reaction, and oxygen transfer into solution may well be controlling the reaction and hence the reactor tank sizing. Oxygen transfer is often the dominant factor in agitator design.

Design plant throughput is also influenced by the volume of water to be treated. For example, seasonal changes will determine variations in run-off, much of which may have to be treated. Increased flow may be accompanied by a dilution of contaminants, both acid and metal, and the resulting plant influent may require reduced oxidation and/or residence time, thus compensating for the increased flow.

The near-complete precipitation of the metals as hydroxides in the neutralization process proceeds according to the following reactions:



As implied by the equations above, the products of these reactions are metal hydroxide precipitates and calcium sulfate (gypsum). If the sulfate concentration of the wastewater is high enough, there will be sufficient gypsum produced to exceed its solubility and it will precipitate with the sludge.

The main features of the HDS process can be summarized as follows. Lime and recycled sludge are added to the lime-sludge mix tank at the head of the process, providing the main neutralization agent. This mixture is discharged to the lime/sludge tank where it is mixed with influent, thereby achieving neutralization. This mixture is fed to lime reactor 1 and lime reactor 2 where a combination of aggressive aeration and high shear agitation ensures optimum process chemistry and subsequent clarifier performance. The discharge from the lime reactor is treated with flocculant. In the final step, the clarifier separates the treated effluent from the sludge, a portion of which is recycled to the head of the process.

The HDS process is normally run at a pH between 9.0 and 9.5, as most metals will precipitate at or below this pH. Oxidation of ferrous to ferric iron takes place rapidly at this pH, with air being the most common oxidizing agent.

For efficiency, the process relies on sludge recycle from a treated effluent. In most plants, this is achieved in a thickener-style clarifier, which provides pumpable sludge in the underflow as the separated solids product. Recycling sludge from a settling pond or from filters are alternatives but they may present handling problems.

## 2.0 EXPERIMENTAL OUTLINE

The purpose of the bench scale testing was to evaluate the effectiveness of lime treatment at various pH levels and to determine the neutralization pH that will provide the most cost-effective treatment of contaminated waters. The results from the bench scale testing would provide preliminary data for conceptual engineering of the water treatment plant.

Three water sources were provided by UOS for treatment at five pH levels each in order to determine the optimal pH for metals removal. The first water sample was lower pH water with higher metal concentration collected from several discrete mine discharge locations that would be piped down gradient to the WTP. The second water sample was collected from Cement Creek, located adjacent to the probable WTP site and contained lower metal concentration and was at higher pH. The third water sample was collected from the Silver Ledge Mine (South Fork of Cement Creek) and had different water chemistry than the first two samples. The following Table 2-1 lists the feed chemistry for the three water samples provided by UOS for treatment.

Table 2-1. Feed Chemistry

		Sample 1	Sample 2	Sample 3
Starting pH		2.4	3.3	5.6
Element	Units			
Al	mg/L	18.66	10.92	1.15
Cd	mg/L	0.066	0.032	0.002
Co	mg/L	0.150	0.060	0.0157
Cu	mg/L	2.98	1.13	0.022
Fe	mg/L	86.52	25.74	18.41
Mn	mg/L	52.83	20.67	2.43
Zn	mg/L	30.68	12.04	0.70

The test program was designed to determine the optimal pH for metals removal. Data obtained from the treatability study were used to prepare metals solubility

curves that show pH versus metal concentrations in the water phase. Lime utilization and solid generation at each pH point were also determined.

For neutralization tests, lime slurry was used to neutralize the feed samples to five pH levels as described below.

The bench scale neutralization treatment was done by neutralizing a 1.0 litre sample to desired pH level (pH = 7.0, 8.0, 8.5, 9.0 and 9.5) with lime slurry, high agitation and aeration for 1 hour, followed by flocculant addition, settling, decanting the overflow, and analyzing the decant by ICP-MS. The settled sludge was filtered, dried and weighed to determine sludge generation. The results from this study are detailed in Section 3.0.

### 3.0 RESULTS & DISCUSSIONS

Three water sources collected from various sites and representing different feed chemistries were tested at five pH levels to determine metals concentration in the effluent, neutralizing reagent consumption, and solid generation data. The data from this study along with design criteria provided by UOS would then be used to prepare a conceptual design and cost estimate for an HDS plant. The complete neutralization test results are attached in Appendix A.

#### 3.1 Lime Consumption & Sludge Production

Table 3-1 and Table 3-2 below show the lime consumption and sludge production for the neutralization tests for the three feed samples.

Table 3-1. Neutralizing Agent Consumption

Sample	Starting pH	Lime Consumption (g/m <sup>3</sup> ) to pH:				
		pH 7	pH 8	pH 8.5	pH 9	pH 9.5
Sample 1	2.4	442.5	750.0	1000.0	662.5	942.5
Sample 2	3.3	337.5	370.0	410.0	412.5	612.5
Sample 3	5.6	22.5	30.0	47.5	67.5	142.5

The lime required was higher for Sample 1 than the other two samples due to the higher concentrations of metal and lower pH compared to the other samples. Lab grade calcium hydroxide was used for testing under optimal temperature and agitation; therefore, this result may vary from the field consumption. The lime consumption recorded for the three tests is variable due to the accuracy of measurement at the low consumption rate. The high lime consumption at pH 8.5 for sample 1 is likely due to the error that is introduced as a result of small size of the sample (1 litre) that was treated.

Table 3-2. Sludge Generation

Sample	Starting pH	Solids Generation to pH (g/L):				
		pH 7	pH 8	pH 8.5	pH 9	pH 9.5
Sample 1	2.4	0.38	0.67	0.74	0.64	0.75
Sample 2	3.3	0.28	0.20	0.28	0.30	0.70
Sample 3	5.6	0.02	0.12	0.02	0.15	0.72

The sludge generation rate increased as the neutralizing pH was increased. The sludge generation rate is an important parameter in the design of a water treatment

plant since it affects aeration, mixing requirements, sludge disposal requirements, filtering and pumping needs and clarifier underflow recycle rate. Therefore, it would be desirable to operate the WTP at the lowest possible pH to generate the least amount of solids without sacrificing effluent quality.

### 3.2 Treated Effluent Chemistry

Expected effluent chemistry for the three water sources are shown in Tables 3-3 and 3-4 below. From previous HDS experience, it has been noticed that the effluent quality from different HDS plants are similar. Thus, it is expected that the effluent quality for the Gladstone Site Water Treatment plant would be similar to other HDS plant effluents and should meet reasonable discharge criteria.

Table 3-3. Before and After Treatment

Sample	pH	Conductivity (mS/cm)	Alkalinity (mg CaCO <sub>3</sub> /L)	Acidity (pH 4.5) (mg CaCO <sub>3</sub> /L)	Total Acidity (pH 8.3) (mg CaCO <sub>3</sub> /L)	Sulphate (mg/L)
Sample 1 Feed	2.40	2.65	<1.0	186.0	378.0	1478
Sample 1 pH 7	7.04	4.37	51.5	<1.0	13.0	1432
Sample 1 pH 8	8.05	3.90	50.8	<1.0	5.0	1457
Sample 1 pH 8.5	8.47	3.05	50.0	<1.0	<1.0	1382
Sample 1 pH 9	8.96	2.31	44.5	<1.0	<1.0	1462
Sample 1 pH 9.5	9.48	2.25	34.8	<1.0	<1.0	1431
Sample 2 Feed	3.30	1.67	<1.0	82.3	192.5	808
Sample 2 pH 7	6.95	1.42	32.8	<1.0	7.3	764
Sample 2 pH 8	8.00	1.42	32.8	<1.0	4.5	782
Sample 2 pH 8.5	8.54	1.43	35.5	<1.0	0.5	773
Sample 2 pH 9	8.94	1.44	33.8	<1.0	<1.0	766
Sample 2 pH 9.5	9.47	1.43	45.8	<1.0	<1.0	791
Sample 3 Feed	5.58	1.03	7.3	<1.0	12.3	536
Sample 3 pH 7	7.10	1.05	23.5	<1.0	2.3	554
Sample 3 pH 8	7.95	1.06	26.5	<1.0	1.8	567
Sample 3 pH 8.5	8.52	1.06	31.0	<1.0	<1.0	535
Sample 3 pH 9	8.97	1.07	39.0	<1.0	<1.0	536
Sample 3 pH 9.5	9.45	1.06	27.5	<1.0	0.8	525

**Table 3-4. Dissolved Metals Before and After Treatment**

		Sample 1					
		Feed	pH 7	pH 8	pH 8.5	pH 9	pH 9.5
Element	Units						
Al	ppm	18.666	0.066	0.11	0.291	0.47	1.227
Cd	ppm	0.06618	0.03208	0.01618	0.00268	0.00076	<0.0005
Co	ppm	0.15035	0.16131	0.0662	0.02156	0.0079	0.00108
Cu	ppm	2.9811	0.0297	0.0293	0.0188	0.0148	0.0133
Fe	ppm	86.52	<0.1	<0.1	<0.1	<0.1	<0.1
Pb	ppm	0.072	0.0011	0.001	<0.001	0.0138	0.0013
Mn	ppm	52.83877	45.23937	37.84059	20.77216	18.35233	2.95067
Zn	ppm	30.6838	7.6933	2.1397	0.245	0.0265	0.0228

		Sample 2					
		Feed	pH 7	pH 8	pH 8.5	pH 9	pH 9.5
Element	Units						
Al	ppm	10.926	0.066	0.081	0.104	0.223	0.299
Cd	ppm	0.03267	0.01554	0.00961	0.00431	0.00122	0.0002
Co	ppm	0.06078	0.05034	0.04601	0.03545	0.00857	0.00503
Cu	ppm	1.1319	0.023	0.0167	0.0129	0.0118	0.0125
Fe	ppm	25.742	0.028	0.034	0.034	0.028	0.032
Pb	ppm	0.0386	<0.0001	<0.0001	0.002	<0.0001	0.0002
Mn	ppm	20.67809	18.99184	18.57248	17.10678	7.2364	2.28451
Zn	ppm	12.0452	3.3112	1.1405	0.2462	0.076	0.0483

		Sample 3					
		Feed	pH 7	pH 8	pH 8.5	pH 9	pH 9.5
Element	Units						
Al	ppm	1.156	0.064	0.096	0.106	0.096	0.05
Cd	ppm	0.00164	0.00079	0.00037	0.00022	<0.00005	<0.00005
Co	ppm	0.01573	0.01433	0.01227	0.01095	0.00728	0.00409
Cu	ppm	0.022	0.0091	0.0076	0.0067	0.0067	0.0077
Fe	ppm	18.418	0.031	0.028	0.032	0.035	0.037
Pb	ppm	0.0075	<0.0001	<0.0001	<0.0001	0.0001	0.0003
Mn	ppm	2.43315	2.38527	2.26145	2.15262	1.78189	0.65948
Zn	ppm	0.7048	0.2563	0.0812	0.0319	0.0155	0.0199

The dissolved metals analyses in the above Table 3-4 were carried out on samples collected before and after bench scale HDS simulation treatment; detailed results

are shown in Appendix A. Metals of concern are cadmium, copper, lead, manganese and zinc. Figures 3-1, 3-2 and 3-3 below show the metal solubility curves for each feed sample.



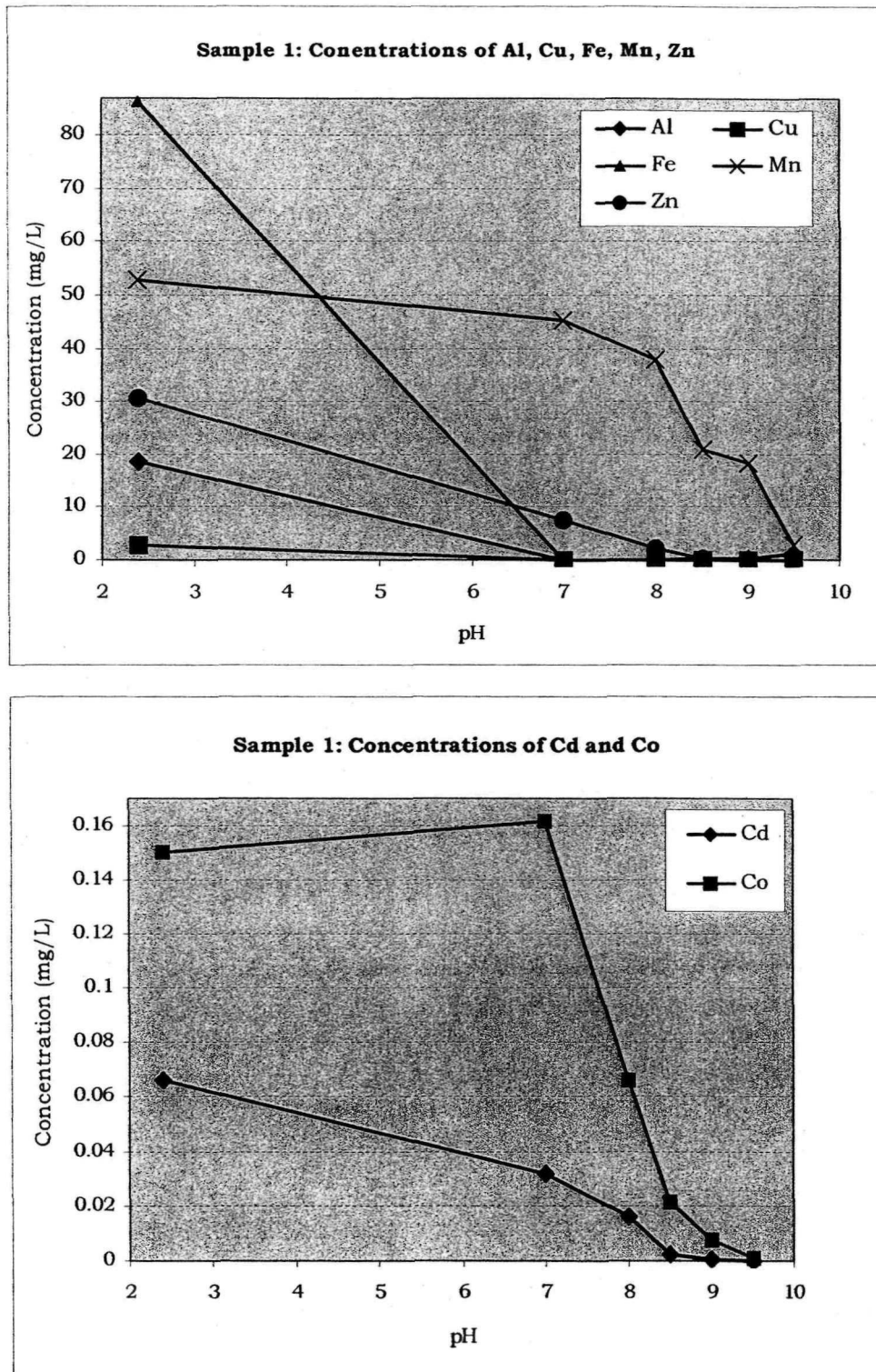


Figure 3-1. Solubility curve for Sample 1 collected from several discrete mine discharge locations

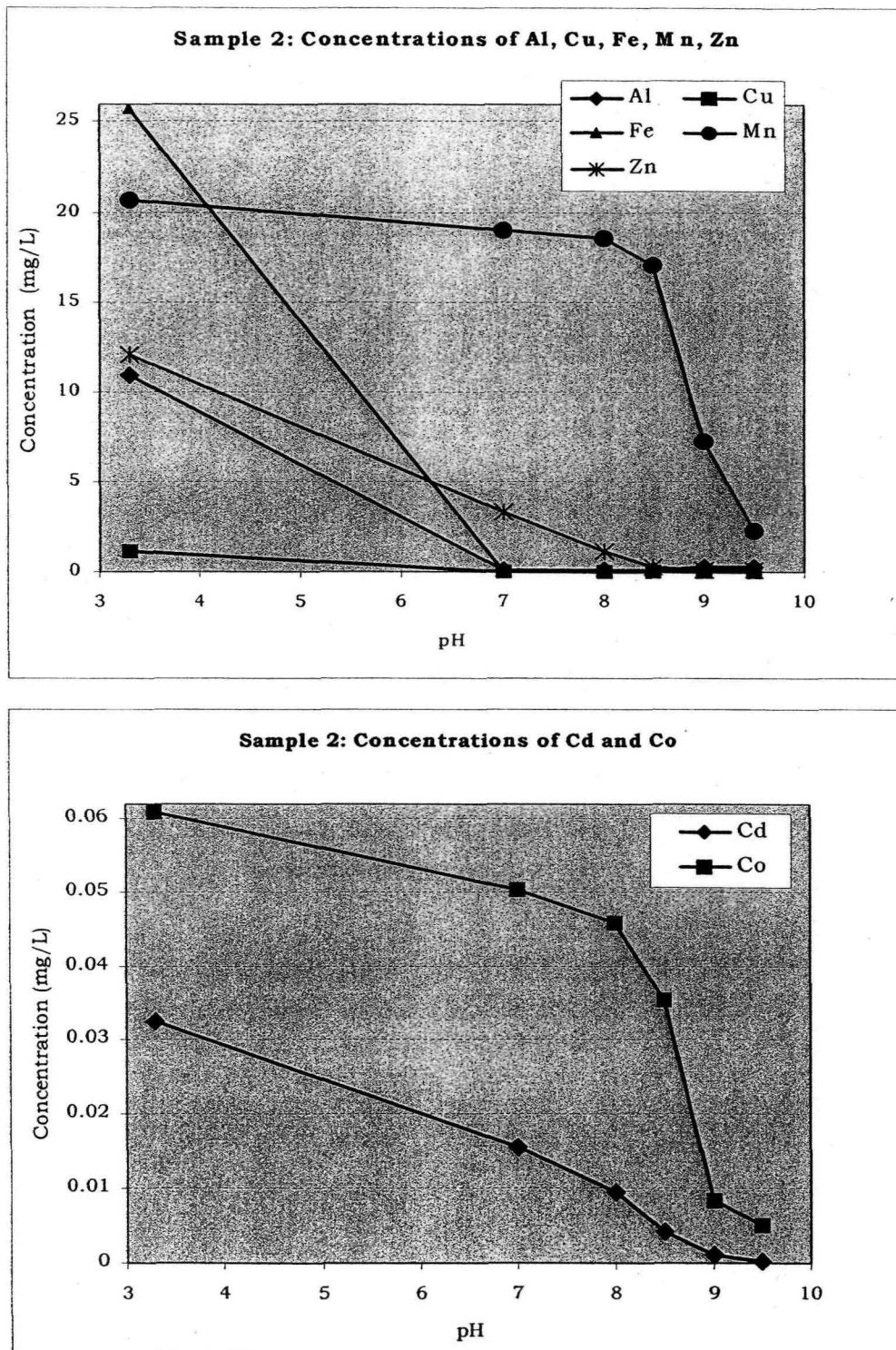


Figure 3-2. Solubility curve for Sample 2 collected from Cement Creek, located adjacent to the probable WTP site

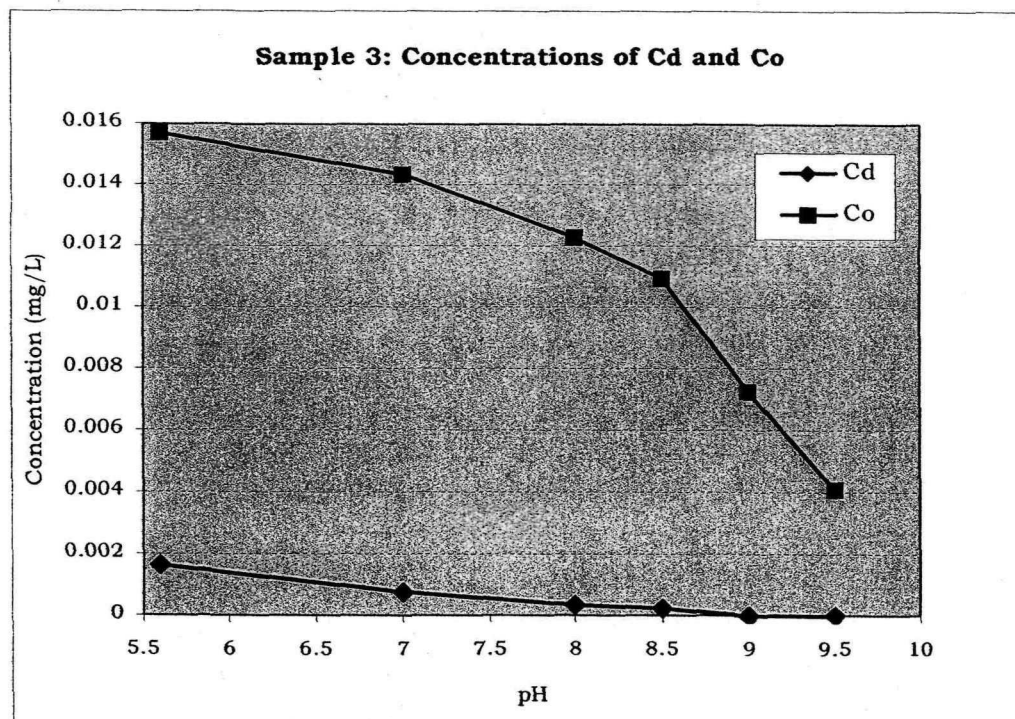
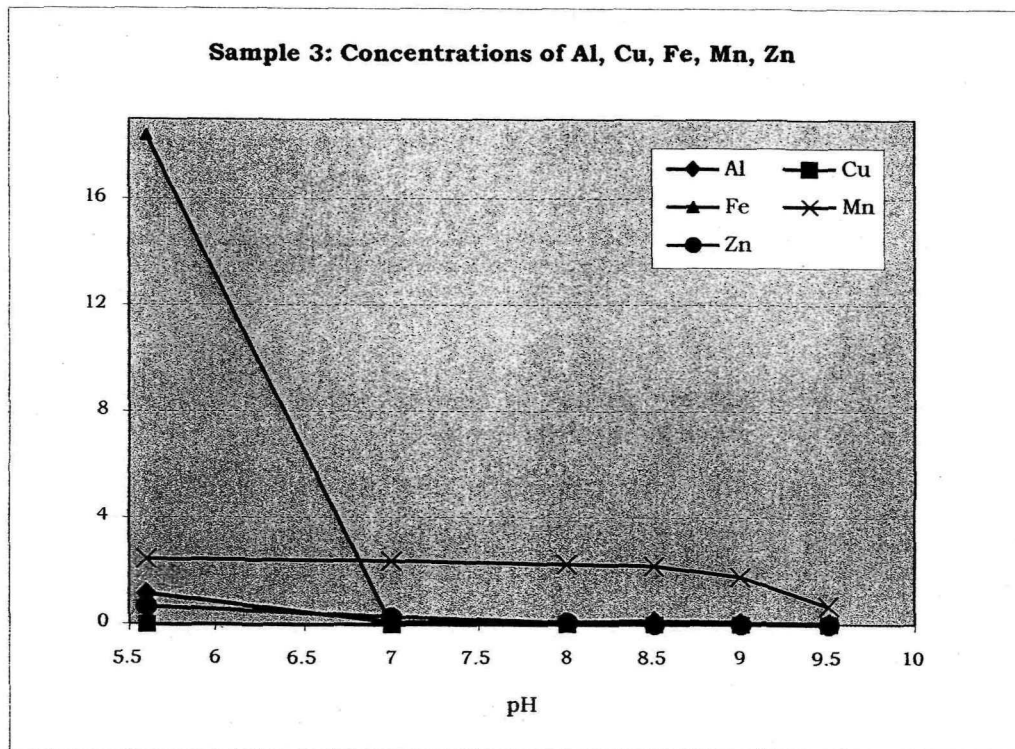


Figure 3-3. Solubility curve for Sample 3 collected from the Silver Ledge Mine (South Fork of Cement Creek)

Operating a plant at pH 9.0 should produce an effluent that would meet reasonable discharge limits for all metals of concern except manganese. The HDS process is normally run at a pH between 9.0 and 9.5 due to several reasons previously discussed in Section 1.2. The metals concentration of the three feed samples after neutralization tests at pH 9.0 is compared to the expected discharge criteria of aquatic water in Table 3-5 below.

**Table 3-5. Comparison of Effluent Quality to Aquatic Life Criteria**

	Colorado Table Value Standard - Acute	Colorado Table Value Standard - Chronic	Sample 1 @ pH 9.0	Sample 2 @ pH 9.0	Sample 3 @ pH 9.0
Cd	0.017	0.0062	0.00076	0.00122	<0.00005
Cu (mg/L)	0.050	0.029	0.0079	0.00857	0.00728
Pb	0.28	0.011	0.0138	<0.0001	0.0001
Mn (mg/L)	4.7	2.60	18.35233	7.2364	1.78189
Zn (mg/L)	0.38	0.38	0.00076	0.00122	<0.00005

The above table indicates that the parameters of concern can be treated to Colorado Table Value Standards for the Animas River Basin with the exception of manganese. Figure 3-4 below illustrates the effect of operating pH on the effluent concentration of manganese and aluminum. As the operating pH increases, the manganese concentration decreases in the effluent, whereas aluminum is dissociated back into the effluent. Based on CEMI's experience, effective pH for manganese removal is between 9.4 and 9.7 with appropriate sludge recycle due to its self catalyzing properties, and for aluminum optimum pH for removal is between 7.0 and 8.0. It may seem that a two-stage system may be required to remove manganese and aluminum; however, all HDS plants that are currently operating in a single stage system are effectively able to remove aluminum and manganese below the discharge criteria. Currently, an HDS water treatment plant in BC, Canada is being engineered, with CEMI's supervision, to precipitate dissolved metals at pH 9.5 and adjust the clarifier overflow pH to approximately 8.5 with CO<sub>2</sub>.

in order to precipitate dissolved aluminum. With the addition of carbon dioxide, the effluent will also be able to comply with the pH discharge limit (8.5).

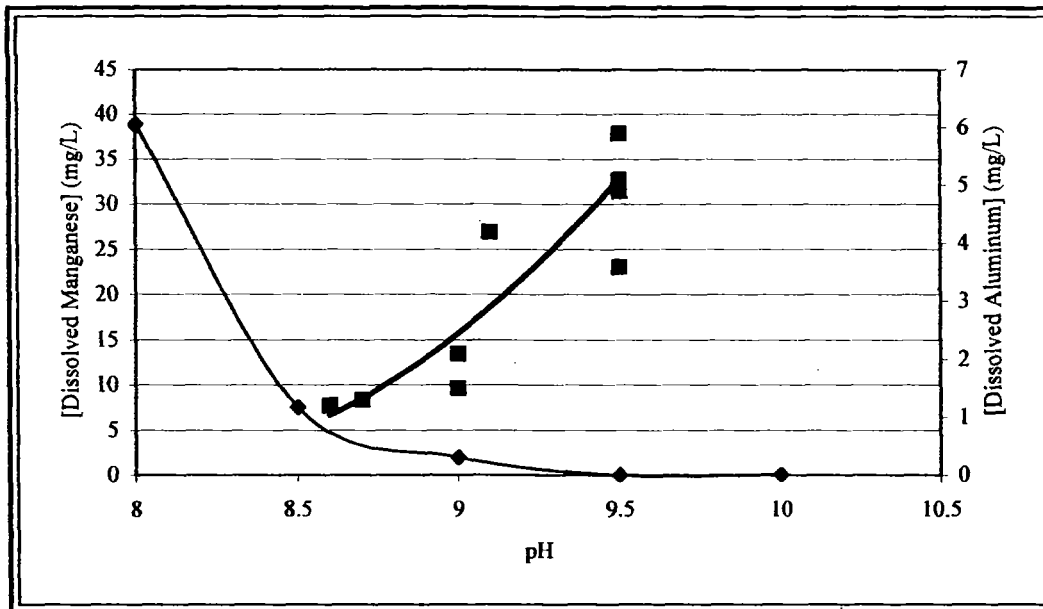


Figure 3-4. Effects of pH on Aluminum and Manganese Concentrations



## 4.0 PROCESS CRITERIA

As requested by UOS, two models and cost estimates were prepared based on the provided criteria. The average treatment flowrate was provided by UOS to be 500 gpm for Sample 1 and 1200 gpm for Sample 2. The water treatment plant for Sample 1 (WTP-S1) is designed to treat a flow of 500 gpm (114 m<sup>3</sup>/hr) for normal operating conditions with a hydraulic capacity of 1000 gpm (227 m<sup>3</sup>/hr). Similarly, the treatment plant for Sample 2 (WTP-S2) is designed to treat a flow of 1200 gpm (272 m<sup>3</sup>/hr) for normal operating conditions with a hydraulic capacity of 2010 gpm (455 m<sup>3</sup>/hr). The material balances and process design criteria for the design flow and maximum flow are provided in Appendices B1 & B2.

The operating pH for the plant was determined to be 9.0 as per UOS. For a proper HDS system, hydraulic retention time of 60 minutes was selected because of the slow reaction of sulfate precipitation as well as complete oxidation of dissolved metals. High retention time also yields higher lime efficiencies since lime is a very slow reactant.

### 4.1 Process Design Chemistry

Water samples from two sources were sent to CEMI for neutralization treatment testwork. Samples were analyzed and the results were used to determine the input parameters for the treatment plant design. The design chemistry used for the conceptual design is the same as the water quality of the sample provided by UOS, as summarized in Table 4-1.

Table 4-1. Design Chemistry\*

Elements	Sample 1	Sample 2
Aluminum	18.66	10.93
Cadmium	0.066	0.033
Cobalt	0.15	0.06
Copper	2.98	1.13
Iron	86.52	25.74
Manganese	52.84	20.68
Zinc	30.68	12.05
SO <sub>4</sub>	1478	808

\*all concentrations in mg/L

#### 4.2 Effluent Quality

Please refer to Section 3.2 – Treated Effluent Chemistry.

#### 4.3 Sludge Production

Theoretical sludge production was calculated based on the influent water chemistry summarized in Section 4.1. The theoretical sludge production shown in Table 4-2 includes 5% of lime as inerts and 5% as unreacted lime.

Table 4-2. Sludge Production

	Sludge Production	
	Theoretical (kg/m <sup>3</sup> )	Experimental (kg/m <sup>3</sup> )
WTP-S1	0.48	0.64
WTP-S2	0.21	0.30

It should be noted that the calculated theoretical sludge production does not include any total suspended solids that may be entrapped in the sludge. Based on the theoretical data, the yearly sludge production at 25% solids will be approximately 2113 tons (1917 tonnes) for WTP-S1 operating at 500 gpm and 2195 tons (1991 tonnes) for WTP-S2 operating at 1200 gpm

#### 4.4 Sludge Recycle

Recycled thickened sludge is a fundamental aspect of the HDS process. The amount of sludge that can be recycled has practical limits in terms of the volume of recycled sludge versus incoming contaminated water volumes, and these volumes have a significant impact on the vessel sizes, reactor residence times, as well as flocculant consumption. It is critical to maintain the recycle ratio at an appropriate level. Based on the other water treatment plants with similar chemistries, the sludge recycle ratio (by solids) is predicted to be 36:1 (recycle:inflow) for WTP-S1 and 56:1 for WTP-S2. To obtain an efficient site-specific sludge recycle ratio, an onsite pilot plant study is recommended.

#### 4.5 Air Requirements

Air requirement is based on iron and manganese concentration in the feed water, and it was assumed that all the iron in the feed is present in ferrous form. The theoretical air requirement for WTP-S1 is 54 m<sup>3</sup>/hr (32 SCFM) at a flowrate of 500 gpm with iron concentration of 86.5 mg/L and manganese concentration of 52.8 mg/L (details provided in Appendix-B1). Similarly, the theoretical air requirement for WTP-S2 is 46 m<sup>3</sup>/hr (27 SCFM) at a flowrate of 1200 gpm with iron concentration of 25.7 mg/L and manganese concentration of 20.7 mg/L. The air requirement for WTP-S1 is higher mostly due to the higher iron and manganese concentrations in Sample 1. It should be noted that an oxygen transfer efficiency of 20% was assumed for the calculations.

Air requirement was also taken into consideration for the reactor sizing. Air requirement has very significant impact on the reactor sizes; therefore, it is highly recommended to confirm and obtain an accurate air requirement through an on-site pilot plant study.

#### 4.6 Theoretical Lime Consumption

Theoretical lime consumption calculations are summarized in Table 4-3 below and was calculated based on feed chemistry and amount of hydroxide in the precipitates. It was determined that for every gram of hydroxide, 2.18 grams of Ca(OH)<sub>2</sub> and 1.65 grams of CaO (100% purity) is required.

Table 4-2. Theoretical Lime Consumption

	Feed Flowrate (gpm)	Lime Consumption	
		(g (CaO)/L)	(ton (CaO)/day)
WTP-S1	500	0.38	1.06
WTP-S2	1200	0.17	1.14

CEMI's experience is that when lime consumption is above 200 tpy, it is cost effective to use CaO rather than Ca(OH)<sub>2</sub>. CaO needs slaking which is labour intensive and requires higher capital cost and maintenance; however, it is less expensive of the two.



#### **4.7 Clarifier Design**

Clarifier size is mainly dependent on the total suspended solids (TSS) concentration allowed in the clarifier overflow. In order to obtain low TSS in the discharged water, a larger clarifier is necessary. For this conceptual design, a typical clarifier rise rate of 1.1 was used to determine the clarifier size. The clarifier for WTP-S1 is sized at 12 m (39 ft) in diameter and for WTP-S2 is sized at 18 m (60 ft) in diameter.

## 5.0 CONCEPTUAL DESIGN

CEMI developed two conceptual designs for the WTP for the Gladstone site. The contaminated water will be treated in the HDS process that utilizes hydrated lime for the precipitation of heavy metals. Treated water will be separated from the produced sludge by a clarifier and discharged. Detailed design information for both designs is provided in Appendix B, conceptual process flow diagrams are provided in Appendix C, and conceptual plant general arrangements are provided in Appendix D.

### 5.1 *Water Management*

The HDS WTP will operate most effectively if the quantity and quality of the water are maintained at relatively constant levels. The solution will undergo treatment to pH 9.0 at a controlled average rate of 500 gpm (114 m<sup>3</sup>/hr) for WTP-S1 and 1200 gpm (273 m<sup>3</sup>/hr) for WTP-S2.

### 5.2 *Process Description*

The contaminated water will be gravity fed through a HDPE line into lime reactor 1 where it will be mixed with a lime/sludge mixture from the lime/sludge mix tank. The discharge from lime reactor 1 will gravity overflow to lime reactor 2. Reactor 2 will overflow by gravity via an upcomer into the clarifier feed pipe and the pipe will carry the slurry flow into the clarifier feedwell. Flocculant will be added in the clarifier feed pipe and mixed with an in-line static mixer. The amount of flocculant added will be based on the mass flow of plant feed in lime reactor 1. Additional flocculant addition points will be available at the clarifier feedwell. From the clarifier, the particles will settle into a solids rich sludge while clarified solution will report to the overflow launder and into the clarifier overflow tank. The treated water solution will be discharged to Cement Creek. This solution will be monitored for pH and turbidity. Periodic samples will be taken for metals analysis at a qualified analytical laboratory. The clarifier underflow, a sludge containing approximately 25% solids, will be continuously recycled back to the lime/sludge mixing tank.

Periodically, as the sludge bed builds up in the clarifier, sludge will be purged from the system and stored on-site in sludge ponds for disposal.

The flocculant preparation system will consist of a vendor-supplied equipment package that will automatically prepare and condition flocculant at 0.5% (by weight). Flocculant mixing will require the use of fresh water. The flocculant solution will be metered to the process with a variable speed dosing pump. The solution will be further diluted with fresh water at a ratio of 10:1 in a static mixer before delivery to the process at the clarifier feed launder and feedwell. Flocculant addition will be controlled by ratio to the quantity of feed flow into the plant.

From the hydrated lime slurry storage tank, the lime will be fed to the lime/sludge mix tank as required via a circulating lime slurry loop. The lime loop will allow good control of pH within lime reactor 1.

Sludge recycled from the clarifier underflow is mixed with lime slurry in the lime/sludge mix tank. The lime addition rate into the lime/sludge mix tank is controlled by a feedback control loop monitoring the pH (9.0) of the slurry in lime reactor 1.

Fresh water is required for flocculant mixing and dilution water, pump gland service, washing, emergency showers and non-potable domestic use. Pressure within the plant will be boosted by the use of booster pumps.

Recycle water, withdrawn from the clarifier overflow and piped to the suction side of the sludge recycle and sludge transfer pumps, will be used for flushing on the shutdown of any of the sludge pumping systems.

The following pumping systems shall have an installed spare when the plant is operating:

- Lime Circulating Pump
- Flocculant Feed Pump

- Sludge Recycle Pump
- Sludge Transfer Pump

All spillage from the lime slurry storage tank area will be collected in the plant sump. The spillage will be pumped from the sump to lime reactor 1 for treatment. In addition, the flocculant area will have a separate containment curb within the main tank sump area to prevent the presence of a widespread slipping hazard. All spillage from the clarifier will be collected in the clarifier sump and pumped to lime reactor 1.

## **6.0 PROCESS TREATMENT DEVELOPMENT**

### **6.1 *Infrastructure***

This conceptual study does not address the design or existing state of the infrastructure except as to comment upon the needs for the purpose of the WTP.

#### **6.1.1 Fresh Water System**

Fresh water will have to be supplied to the WTP. The design and cost of this system lies outside the scope of this study. At **average flowrate**, approximately 4.4 gpm (1 m<sup>3</sup>/hr) of fresh water for WTP-S1 and 7 gpm (1.6 m<sup>3</sup>/hr) of fresh water for WTP-S2 will be required. The majority of this water is required for flocculant mixing.

Fresh water will be supplied to:

- Flocculant Preparation System
- Gland Water System
- Emergency Showers

The water will have to be non-corrosive in nature with a minimum of suspended solids.

#### **6.1.2 Power**

Power will be supplied to the Motor Control Centre (MCC) from the existing grid. The provision of this power and the engineering associated with it lies outside the scope of this conceptual engineering study.

### **6.2 *Plant Feed System***

This system will pump feed solution at controlled rate.

### **6.3 *Main Process Building***

The main process building will have to be of sufficient size to enclose the area indicated in the general arrangement drawing (Plan) and of sufficient height to

cover the tops of the process equipment as indicated. The main process building will be composed of the areas described below.

#### **6.3.1 Containment Area**

A concrete floor is required in the main process building to control spillage. The slope will be sufficient to direct the flow of water with solids to the sump trench. The containment area will be sufficient to allow for controlled cleanup. To assist in clean up there will be a trench located down the middle of the containment area. Discharge from the sump area will be via the plant area sump pump located in a sump hole, which will be part of the trench.

#### **6.3.2 Process Equipment Area**

All the process equipment will be located within the containment area of the main process building.

#### **6.3.3 Flocculant Area**

Flocculant will be mixed in the main process building. No provision is made for the movement of materials by crane. It is assumed that mobile equipment with forklift capability will be present at the site. A containment curb will be placed around the flocculant area.

### **6.4 Reagent Systems**

#### **6.4.1 Lime System**

The lime system has been designed based on theoretical hydrated lime consumption of up to 1 ton/day. The existing lime equipment may be used in the plant; however, without an equipment field inspection it is difficult to make any reasonable comments.

##### **6.4.1.1 Lime Slurry Storage Tank**

The lime slurry storage tank will be a baffled carbon steel tank, 2.0 m in diameter and 3.0 m high (for both flow designs), and it will be placed on a concrete base. Discharge from the tank will be via the lime circulating pumps.

#### **6.4.1.2 Lime Circulating Loop**

The lime circulating pumps will feed a circulating loop at a rate approximately 3-4 times the withdrawal rate. Takeoffs will be located at the lime/sludge mixing tank and the lime reactor. Two centrifugal lime slurry pumps, one operating and one installed spare, will continuously circulate lime slurry through a mild steel piping system back to the lime slurry storage tank with take-offs controlled by pinch valves to the lime/sludge mixing tank and lime reactor. Only the pinch valve to the lime/sludge mix tank will be controlled by the pH unit in the lime reactor.

Only where constant maintenance is required is there duplication. In the case of the lime preparation circuit, these are the lime circulating pumps. Certain critical spares will have to be maintained including spare pinch valves.

#### **6.4.2 Flocculant System**

The flocculant system will be based on a vendor supplied equipment package which will include mix agitator, tanks, pumps, wetting head, etc. The flocculant system will be in the main process building.

##### **6.4.2.1 Flocculant Preparation**

Dry flocculant will be supplied in bags and mixed with fresh water to a concentration of 0.5% (by weight) using an automated polymer feed and mixing system. Suitably aged flocculant will be transferred from the flocculant mixing system to the flocculant holding tank using a transfer pump. The flocculant solution will be discharged from the flocculant holding tank by a variable speed dosing pump. The 0.5% strength flocculant solution will be further diluted with fresh water at a ratio of a minimum 10:1 in a static mixer before delivery to the clarifier.

Fresh water will be used for both flocculant mixing and dilution. Provision has also been made to permit the use of clarifier overflow solution for dilution.

#### **6.4.2.2 Flocculant Distribution**

The process destinations for the flocculant will include the contact mix box prior to the clarifier feed pipe and the clarifier feedwell. Flocculant distribution will be by carbon steel lines with valves for isolation. The rate of dosage will be controlled by a variable speed dosing pumps (progressive cavity).

### **6.5 Process Equipment (Tanks & Mechanical)**

#### **6.5.1 Tank Support Structures**

The lime reactor tanks, the lime slurry storage tank, and the clarifier should all be located on concrete to be designed by others. The top of the lime/sludge mix tank will be at a level above the top of lime reactor #1. These tanks are all situated inside the main process building.

#### **6.5.2 Lime/Sludge Mix Tank**

This tank will be a baffled carbon steel tank sitting on structural steel. For WTP-S1, the tank is sized to be 0.8 m in diameter and 1.3 m high while WTP-S2 tank is sized to be 1.0 m in diameter and 1.5 m high. It will include an agitator to provide a high level of agitation for the viscous lime/sludge material. Discharge will be to lime reactor 1. The tank will have a drain valve and overflow line (the same line as from the drain line).

#### **6.5.3 Lime Reactors**

The lime reactor tanks will be baffled carbon steel tanks and they will be sand blasted and primed. For WTP-S1, the tank is sized to be 4.8 m in diameter and 6.3 m high while WTP-S2 tank is sized to be 5.9 m in diameter and 7.4 m high. The retention time provided in the reactor tanks is sufficient to produce an effluent that meets discharge quality under normal flow conditions, and under high flow events. The tanks will have an agitator running a 45-degree pitched blade propeller. The tanks will be fitted with SparJets for aeration and oxidation. The SparJets will utilize compressed air. Discharge from tank will be via an upcomer. The open top upcomers will allow visible confirmation of process conditions.



The tanks will have a drain valve, a man access door (located near the bottom of the tank), and an overflow line.

Sufficient opportunities should exist during periods of average flow to shut down and perform the required maintenance on the agitator. Certain spares, such as spare motors, will have to be maintained. In the event of agitator failure during peak flows, it should still be possible to maintain adequate mixing through the use of additional high-pressure air in the SparJets.

#### **6.5.4 Clarifier**

In this study the clarifier design will be a standard capacity conventional unit. A bridge which will include a walkway with grating will support the rake mechanism. The rake drive system will have continuous torque sensing devices and be equipped with an automatic lifting device and a high torque alarm. Automatic shutdown will occur at extremely high torque to protect the rake mechanism. The clarifier will be elevated on structural steel supports. The bottom of the clarifier will be open.

#### **6.5.5 Clarifier Overflow Discharge Pipelines to Treated Water Pond**

The clarifier overflow launder will flow into the clarifier overflow tank. The clarifier overflow can be discharged directly to the environment or a treated water polishing pond in case there is small amount of solids carry over.

#### **6.5.6 Recycle Water System**

Recycle water will be provided by a takeoff from the treated water pump discharges. The water produced in the overflow of the clarifier will be of sufficient quality to be used for a number of tasks around the plant including:

- Flocculant Dilution
- Fire Suppression
- Flush Water (Clarifier Sludge Discharge and Recycle Lines)

#### **6.5.7 Fresh Water System**

The fresh water system will provide fresh water sufficient for pump gland service, flocculant mixing, and flocculant dilution. These two pumps (or one pump) and a fresh water tank will be located inside the main process building. This system will also provide minor water for washing within the plant. Others are to provide the supply of the fresh water to within 2 meters of the main process building.

#### **6.5.8 Sludge Recycle System**

The sludge recycle system will consist of two variable speed centrifugal pumps, one of which will normally be the standby unit. In situations where higher recycle ratio is required or the plant is dealing with peak flows, both pump systems will be active. In addition, in the seasonal commissioning of the plant, provision has been made to utilize one of the larger sludge discharge pump systems to provide higher levels of recycle needed for startup (in this case a temporary line will be put in place). Both of these units will be located under the clarifier. The pumps will discharge to the lime/sludge mixing tank.

Recycle solution will be piped directly into the feed lines of these pumps to provide flush capability.

#### **6.5.9 Sludge Discharge System**

The sludge discharge system could be operated on a continuous or periodic basis. Initiation may be either by the process control system or by manual means.

#### **6.5.10 Launders and Walkways**

Carbon steel pipes will provide gravity flow between the process tanks. Standard guard railings and kick plates need to be provided for all walkways above ground level, as well as stairways and all tank platforms and bridges.

## **6.6     *Electrical***

This study includes costing of electrical components (within battery limits) of the WTP including the motors for the process equipment.

## **6.7     *Process Control Philosophy***

The field instruments and the communications systems are described below. The hardware and software cost of providing communications to a remote monitoring system outside the confines of the WTP area has been included.

### **6.7.1     *Control Hardware***

The control system will consist of a Programmable Logic Controllers (PLC) and associated I/O modules to make the plant fully automatic with minimal operator intervention. The proposed level of instrumentation facilitates an efficient and reliable process.

The control equipment will be mounted in two MCC sections and stacked with the rest of the MCC line-up. This configuration ensures reliable and cost effective installation. The control panels are divided between an analog and a discrete panel.

### **6.7.2     *HMI Operator Graphical Interface***

The operator interface will run on a single desktop type computer. This computer will communicate to the process via a plant control network (Ethernet). This network will be separate from any office networks running at site. Included with the HMI software is a historical database that will store analog and discrete data for reporting purposes. The operator can leave the plant running in automatic, or switch it to manual and control all the equipment by starting and stopping it individually. The HMI software also generates process alarms that will be displayed in graphical format on the interface computer.

The design includes a hardware dialer that will initiate phone/radio calls when certain process parameters are outside allowable tolerances. These parameters

will be grouped and summarized by the control system to minimize the hardware requirement. The remote operator has the capability to acknowledge alarms as well as giving some basic commands to correct the problem if possible.

### 6.7.3 Instrumentation

Field instrumentation is summarized below for the plant.

Screw Conveyor Startup System	1 units
Magnetic Flowmeters	1 units
Process pH Meter	3 units
Density Gauges and Transmitters	3 units
Turbidity Transmitter	1 unit
Level Transmitter	4 units
On/Off Valve (Knife Gate)	27 units
On/Off Valve (Ball)	35 units
On/Off Solenoids	2 units
Variable Valve (Pinch)	6 units
Level – Float Switch	2 units
Torque Indicator	1 unit
Rotameter	2 unit
Variable Frequency Drives	4 units
High Level Alarms	3 units

Instrumentation failure is not seen as a major threat to the operation of the plant. It should be possible to maintain sufficient plant performance if there are problems with the control system although the situation will require more labour. Spare parts should be maintained on-site to provide immediate replacement.

## 7.0 CAPITAL AND OPERATING COST ESTIMATES

This conceptual study only addresses the capital cost of the major process equipment within the WTP. Table 7-1 summarizes the capital and the operating costs for both designs. The capital and operating costs for treatment plant is estimated at +/- 30%. Only direct costs are included in the capital costs. The direct cost does not include site preparation, engineering costs, taxes, and other indirect costs. All external requirements of water treatment, such as surge ponds, sludge ponds, or water collection systems are not part of this costing study.

Table 7-1. Capital and Operating Costs

	Capital (US \$)	Operating Costs	
		Annual (US \$)	Normalized (US \$/ 100 gallons of Feed)
WTP-S1	\$ 3,500,000	\$ 364,390	\$ 0.14
WTP-S2	\$ 4,800,000	\$ 437,211	\$ 0.07

Table 4-2 and 4-3 below shows the operating cost for the designed plants. Reagent costs were based on treating water at the rate provided by UOS for the entire year so does not include the extra reagent required to treat greater than the design flows during periods of peak runoff. O&M costs typically include power, labor and equipment maintenance and does not include routine sampling and sample analysis.

Labor cost is estimated with a plant that is maintained and operated efficiently. Overall operating costs are better estimated by the owners. CEMI can only recommend operational labor based on experience at other sites.

Table 4-2. Operating Costs Estimates For WTP-S1

Reagent	Dose Rate (mg/L plant feed)	Annual Average Plant Flow Rate (L/min)	Annual Reagent Consumption (tonnes/year)	Reagent Unit Cost (US\$/tonne)	Annual Reagent Cost (US\$/year)
Hydrated Lime	488	1,893	485.4	140	67,958
Flocculant	1	1,893	1.0	3600	3,581
Sub-total:					\$71,540
Item	Annual Consumption			Unit Cost (US\$)	Annual Cost (US\$/year)
Electric Power <sup>1</sup>				0.04	60,000
O & M Capital	3 % of capital cost			3500000	105,000
O & M Labour	10 hours per day			35	127,750
Sub-total:					\$292,750
Total Annual Operating Cost:			\$364,290 /year	(US dollars)	
<sup>1</sup> Assumed cost of \$0.04/kW hour					

Table 4-3. Operating Costs Estimates For WTP-S2

Reagent	Dose Rate (mg/L plant feed)	Annual Average Plant Flow Rate (L/min)	Annual Reagent Consumption (tonnes/year)	Reagent Unit Cost (US\$/tonne)	Annual Reagent Cost (US\$/year)
Hydrated Lime	219	4,542	522.6	140	73,171
Flocculant	2	4,542	4.8	3600	17,190
Sub-total:					\$90,361
Item	Annual Consumption			Unit Cost (US\$)	Annual Cost (US\$/year)
Electric Power <sup>1</sup>				0.04	75,000
O & M Capital	3 % of capital cost			4800000	144,000
O & M Labour	10 hours per day			35	127,750
Sub-total:					\$346,750
Total Annual Operating Cost:			\$437,111 /year	(US dollars)	

<sup>1</sup>Assumed cost of \$0.04/kW hour

## 8.0 RECOMMENDATIONS

Following are some recommendations that are essential before proceeding with the planning and construction of a water treatment plant.

- On-site pilot plant is highly recommended to verify the quality of the effluent and determine important parameters such as reagent consumption and other engineering data needed for the design of the water treatment plant
- Seasonal profile is required so variance in climate can be evaluated
- Flows should be further defined so plant can be designed to handle the expected peak flows

## **APPENDIX A.**

### **Neutralization Test Results**



URS Operating Services Inc. – Gladstone Site  
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ICP-MS/OES		Sample 1					
		Feed	pH 7	pH 8	pH 8.5	pH 9	pH 9.5
Element	Units						
Ag	ppm	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Al	ppm	18.666	0.066	0.11	0.291	0.47	1.227
As	ppm	0.0053	<0.005	<0.005	<0.005	<0.005	<0.005
Au	ppm	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
B	ppm	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ba	ppm	0.00883	0.01228	0.01087	0.0111	0.01028	0.00609
Be	ppm	0.0073	0.00072	0.00072	<0.0005	<0.0005	<0.0005
Bi	ppm	0.0007	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Br	ppm	<0.05	0.068	0.059	0.06	0.064	<0.05
Ca	ppm	425.495	671.157	607.517	705.241	528.539	513.65
Cd	ppm	0.06618	0.03208	0.01618	0.00268	0.00076	<0.0005
Ce	ppm	0.05523	0.00017	<0.0001	<0.0001	<0.0001	<0.0001
Cl	ppm	<10	224	169	254	<10	<10
Co	ppm	0.15035	0.16131	0.0662	0.02156	0.0079	0.00108
Cr	ppm	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cs	ppm	0.00489	0.00423	0.00435	0.0045	0.00426	0.00423
Cu	ppm	2.9811	0.0297	0.0293	0.0188	0.0148	0.0133
Dy	ppm	0.01065	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Er	ppm	0.00421	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Eu	ppm	0.00365	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fe	ppm	86.52	<0.1	<0.1	<0.1	<0.1	<0.1
Ga	ppm	0.00269	0.00145	0.00099	0.00079	0.00052	<0.0005
Gd	ppm	0.0139	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ge	ppm	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Hf	ppm	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Hg	ppm	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ho	ppm	0.00167	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
In	ppm	0.00471	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ir	ppm	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
K	ppm	1.621	1.635	2.378	2.336	1.996	1.818
La	ppm	0.02579	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Li	ppm	0.0525	0.053	0.0512	0.0489	0.0503	0.0514
Lu	ppm	0.00027	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mg	ppm	30.567	30.727	29.811	30.448	28.843	27.878
Mn	ppm	52.83877	45.23937	37.84059	20.77216	18.35233	2.95067
Mo	ppm	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Na	ppm	7.416	6.956	7.7	7.444	7.56	7.722
Nb	ppm	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nd	ppm	0.03426	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ni	ppm	0.066	0.071	0.0265	<0.002	<0.002	<0.002
Os	ppm	<0.0005	<0.0005	0.00095	0.00159	0.00083	<0.0005
P	ppm	0.432	<0.2	<0.2	<0.2	<0.2	<0.2
Pb	ppm	0.072	0.0011	0.001	<0.001	0.0138	0.0013
Pd	ppm	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Pr	ppm	0.00695	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Pt	ppm	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Rb	ppm	0.01462	0.01387	0.01414	0.01423	0.01353	0.01404
Re	ppm	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Rh	ppm	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ru	ppm	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
S	ppm	542	527	553	539	545	548
Sb	ppm	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Sc	ppm	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Se	ppm	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Si	ppm	17.507	6.922	4.061	2.119	1.575	0.895
Sm	ppm	0.00888	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Sn	ppm	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Sr	ppm	4.79268	5.09249	5.08535	5.12158	4.73257	4.87101
Te	ppm	0.00416	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Th	ppm	0.00162	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Ti	ppm	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Tl	ppm	0.00018	0.00021	0.00023	0.00017	0.00017	0.00014
Tm	ppm	0.00049	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
U	ppm	0.00547	0.00172	0.00211	0.00231	0.00081	0.00069
V	ppm	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
W	ppm	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Y	ppm	0.05372	0.00033	0.00028	<0.0001	<0.0001	<0.0001
Yb	ppm	0.00264	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Zn	ppm	30.6838	7.6933	2.1397	0.245	0.0265	0.0228
Zr	ppm	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002

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ICP-MS/OES		Sample 2					
		Feed	pH 7	pH 8	pH 8.5	pH 9	pH 9.5
Element	Units						
Ag	ppm	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Al	ppm	10.926	0.066	0.081	0.104	0.223	0.299
As	ppm	0.0011	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Au	ppm	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
B	ppm	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ba	ppm	0.01813	0.01475	0.01438	0.01438	0.01398	0.01095
Be	ppm	0.00439	0.00012	0.00014	<0.00005	<0.00005	<0.00005
Bi	ppm	0.00011	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Br	ppm	<0.005	0.008	0.007	0.007	0.009	0.008
Ca	ppm	189.483	272.5	271.555	277.917	280.041	273.174
Cd	ppm	0.03267	0.01554	0.00961	0.00431	0.00122	0.0002
Ce	ppm	0.02886	0.0003	0.00012	0.00005	0.00002	0.00001
Cl	ppm	<1	1	1	2	5	<1
Co	ppm	0.06078	0.05034	0.04601	0.03545	0.00857	0.00503
Cr	ppm	0.0014	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cs	ppm	0.0014	0.00129	0.00118	0.00125	0.00136	0.00125
Cu	ppm	1.1319	0.023	0.0167	0.0129	0.0118	0.0125
Dy	ppm	0.00573	0.00003	0.00002	0.00001	0.00001	<0.00001
Er	ppm	0.00243	0.00001	0.00001	0.00001	<0.00001	<0.00001
Eu	ppm	0.00177	0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Fe	ppm	25.742	0.028	0.034	0.034	0.028	0.032
Ga	ppm	0.00062	0.00035	0.00038	0.00038	0.0002	0.0001
Gd	ppm	0.00741	0.00005	0.00003	0.00002	<0.00001	<0.00001
Ge	ppm	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Hf	ppm	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Hg	ppm	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ho	ppm	0.00103	0.00001	<0.00001	<0.00001	<0.00001	<0.00001
In	ppm	0.00189	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Ir	ppm	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
K	ppm	0.963	0.945	0.981	2.648	6.899	1.045
La	ppm	0.01447	0.00031	0.00011	0.00004	0.00002	<0.00001
Li	ppm	0.0284	0.0256	0.0278	0.0265	0.0266	0.0266
Lu	ppm	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Mg	ppm	16.021	14.805	15.975	16.264	15.717	15.577
Mn	ppm	20.67809	18.99184	18.57248	17.10678	7.2364	2.28451
Mo	ppm	0.0002	0.0002	0.0003	0.0003	0.0003	0.0004
Na	ppm	4.305	3.919	4.402	4.387	4.377	4.43
Nb	ppm	<0.00001	0.00001	0.00001	<0.00001	<0.00001	<0.00001
Nd	ppm	0.02181	0.00018	0.00009	0.00004	0.00002	0.00001
Ni	ppm	0.0263	0.0209	0.0192	0.0147	0.0023	0.0006
Os	ppm	<0.00005	0.00017	0.00025	0.00024	0.00006	<0.00005
P	ppm	0.104	0.041	0.039	0.041	0.034	0.041
Pb	ppm	0.0386	<0.0001	<0.0001	0.0002	<0.0001	0.0002
Pd	ppm	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Pr	ppm	0.00451	0.00004	0.00001	<0.00001	<0.00001	<0.00001
Pt	ppm	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Rb	ppm	0.00564	0.00547	0.00551	0.00567	0.00611	0.00559
Re	ppm	0.00003	0.00003	0.00003	0.00004	0.00004	0.00004
Rh	ppm	0.00002	<0.00001	<0.00001	<0.00001	<0.00001	0.00001
Ru	ppm	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
S	ppm	272	261	281	276	278	267
Sb	ppm	0.00007	<0.00005	<0.00005	0.00011	0.00006	0.00021
Sc	ppm	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Se	ppm	0.001	0.0006	0.0005	<0.0005	0.0005	0.0005
Si	ppm	12.789	6.599	5.989	5.233	2.813	2.742
Sm	ppm	0.00541	0.00004	<0.00002	<0.00002	<0.00002	<0.00002
Sn	ppm	0.00006	<0.00005	0.00018	<0.00005	<0.00005	<0.00005
Sr	ppm	2.072	2.26529	2.22301	2.21581	2.2246	2.13309
Te	ppm	0.00097	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Th	ppm	0.00084	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Ti	ppm	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tl	ppm	0.00012	0.00011	0.00009	0.00012	0.00011	0.00015
Tm	ppm	0.00029	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
U	ppm	0.00212	0.00061	0.0006	0.00058	0.00058	0.00078
V	ppm	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
W	ppm	0.00004	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Y	ppm	0.02934	0.00039	0.00025	0.00014	0.00008	0.00003
Yb	ppm	0.00161	0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Zn	ppm	12.0452	3.3112	1.1405	0.2462	0.076	0.0483
Zr	ppm	0.00003	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002

URS Operating Services Inc. - Gladstone Site  
Water Treatment Plant  
Conceptual Design

ICP-MS/OES		Sample 3					
		Feed	pH 7	pH 8	pH 8.5	pH 9	pH 9.5
Element	Units						
Ag	ppm	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Al	ppm	1.156	0.064	0.096	0.106	0.096	0.05
As	ppm	0.0034	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Au	ppm	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
B	ppm	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ba	ppm	0.00836	0.00786	0.00702	0.00686	0.00657	0.01222
Be	ppm	0.00153	0.00007	0.00012	<0.00005	<0.00005	<0.00005
Bi	ppm	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Br	ppm	0.005	0.008	0.007	0.006	0.008	0.006
Ca	ppm	201.044	195.023	202.35	202.819	208.599	205.834
Cd	ppm	0.00164	0.00079	0.00037	0.00022	<0.00005	<0.00005
Ce	ppm	0.00297	0.00002	<0.00001	0.00001	0.00001	0.00004
Cl	ppm	<1	1	<1	1	<1	<1
Co	ppm	0.01573	0.01433	0.01227	0.01095	0.00728	0.00409
Cr	ppm	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cs	ppm	0.00134	0.00128	0.00123	0.0013	0.00127	0.00099
Cu	ppm	0.022	0.0091	0.0076	0.0067	0.0067	0.0077
Dy	ppm	0.00054	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Er	ppm	0.00028	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Eu	ppm	0.00014	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Fe	ppm	18.418	0.031	0.028	0.032	0.035	0.037
Ga	ppm	0.00011	0.00011	0.00013	0.00012	0.00009	<0.00005
Gd	ppm	0.00066	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Ge	ppm	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Hf	ppm	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Hg	ppm	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ho	ppm	0.0001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
In	ppm	0.00003	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Ir	ppm	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
K	ppm	0.898	0.916	0.869	1.823	0.96	0.971
La	ppm	0.00145	0.00001	<0.00001	0.00001	<0.00001	0.00002
Li	ppm	0.026	0.0249	0.0264	0.0261	0.0256	0.0249
Lu	ppm	0.00002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Mg	ppm	8.959	8.732	9.22	9.384	9.054	8.939
Mn	ppm	2.43315	2.38527	2.26145	2.15262	1.78189	0.65948
Mo	ppm	0.0015	0.0003	0.0003	0.0008	0.0005	0.0003
Na	ppm	3.297	3.277	3.496	3.563	3.597	3.441
Nb	ppm	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Nd	ppm	0.00188	<0.00001	<0.00001	<0.00001	<0.00001	0.00002
Ni	ppm	0.0035	0.0027	0.0022	0.0016	0.0009	<0.0002
Os	ppm	<0.00005	0.00018	0.00027	0.00022	0.00006	<0.00005
P	ppm	0.091	0.043	0.037	0.036	0.045	0.048
Pb	ppm	0.0075	<0.0001	<0.0001	<0.0001	0.0001	0.0003
Pd	ppm	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Pr	ppm	0.0004	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Pt	ppm	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Rb	ppm	0.00489	0.0049	0.00487	0.00496	0.00477	0.00499
Re	ppm	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Rh	ppm	<0.00001	0.00001	0.00001	0.00001	0.00001	<0.00001
Ru	ppm	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
S	ppm	189	187	193	195	197	197
Sb	ppm	0.00007	<0.00005	<0.00005	<0.00005	<0.00005	0.00016
Sc	ppm	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Se	ppm	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Si	ppm	11.344	8.921	9.003	9.07	8.706	8.116
Sm	ppm	0.00047	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Sn	ppm	<0.00005	<0.00005	<0.00005	0.00027	0.00015	<0.00005
Sr	ppm	2.00216	1.96687	1.98362	2.01136	1.98739	1.89426
Te	ppm	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Th	ppm	0.00008	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Ti	ppm	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tl	ppm	0.00005	0.00006	0.00005	0.00005	0.00004	0.00019
Tm	ppm	0.00003	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
U	ppm	0.00017	0.00006	0.00007	0.00007	0.00008	0.00015
V	ppm	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
W	ppm	0.0012	<0.00002	<0.00002	0.00002	<0.00002	0.00018
Y	ppm	0.00314	0.00004	0.00004	0.00004	0.00002	0.00004
Yb	ppm	0.00017	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Zn	ppm	0.7048	0.2563	0.0812	0.0319	0.0155	0.0199
Zr	ppm	<0.00002	<0.00002	<0.00002	<0.00002	0.00007	<0.00002

## **APPENDIX B1.**

### **Process Design Parameters for Sample 1**

## URS OPERATING SERVICES INC.

### GLADSTONE SAMPLE 1 - ARD TREATMENT

#### Conceptual Design : 2725 m<sup>3</sup>/day

##### Flowrate

Normal Flowrate	2725 m <sup>3</sup> /day
Normal Flowrate	114 m <sup>3</sup> /hr
Normal Flowrate	500 GPM
Max. Flowrate	5451 m <sup>3</sup> /day
Max. Flowrate	227 m <sup>3</sup> /hr
Max. Flowrate	1000 GPM
Feed pH	2.4
Operating pH	9.0

##### Solids

Solids Generations	0.48 g/L
Solids Generations-Max	0.48 g/L
Normal Solids Generations	0.055 ton/hr
Max. Solids Generations	0.109 ton/hr
Normal Sludge Recycle Ratio	36 :1
Max. Sludge Recycle Ratio	36 :1
Percent Solids in Sludge	25.0 %
Sludge Pulp Density	1.17
Clarifier Feed S.G	1.02

##### Vessels - Residence Times

Reactor Vessels	60 minutes
Lime Sludge Mix Tank	4 minutes
Recycle Water Tank	10 minutes
Clarifier Upflow Ratio	1.10

##### Lime

	Normal
Lime Require (CaO)	0.39 kg/m <sup>3</sup>
Lime Requirements (Ca(OH) <sub>2</sub> )	0.51 kg/m <sup>3</sup>
Lime Concentration	20 %
Lime Solid S.G	2.50
Lime Requirement (Ca(OH) <sub>2</sub> )	0.058 ton/hr
Lime Requirement (CaO)	0.044 ton/hr
Lime Recycle IN Ratio	3
Lime Recycle RETURN Ratio	2
Lime to TANKS Ratio	1
Lime Slurry Tanks Holding Time	24 hrs.

##### Flocculent

Flocculent Addition	1 mg/L
Flocculent Addition	0.1 kg/hr
Flocculent Concentration	0.05 %
Flocculent Make Up Water pH	5-7

**Water Quality and Sludge Generation Prediction**  
**URS OPERATING SERVICES INC.**  
**GLADSTONE SAMPLE 1 - ARD TREATMENT**

Ion	Hydroxide Formula	Mass of Ion Present (mg/L)	Mass of Precip. (mg/L)
Al	Al(OH) <sub>3</sub>	18.67	53.97
Ag	AgOH	0.00	0.00
As	As(OH) <sub>3</sub>	0.01	0.01
Bi	Bi(OH) <sub>3</sub>	0.00	0.00
Ca	Ca(OH) <sub>2</sub>	425.50	0.00
Cd	Cd(OH) <sub>2</sub>	0.07	0.09
Cu	Cu(OH) <sub>2</sub>	2.98	4.58
Fe	Fe(OH) <sub>3</sub>	86.52	165.57
Pb	Pb(OH) <sub>2</sub>	0.07	0.08
Mg*	Mg(OH) <sub>2</sub>	30.57	49.35
Mn	MnO <sub>2</sub>	52.84	83.61
Ni	Ni(OH) <sub>2</sub>	0.07	0.10
S*	CaSO <sub>4</sub> ·2H <sub>2</sub> O		0.00
Sb	Sb(OH) <sub>3</sub>	0.00	0.00
Se	Se(OH) <sub>4</sub>	0.00	0.00
Si	Si(OH) <sub>2</sub>	17.51	38.71
Zn	Zn(OH) <sub>2</sub>	30.68	46.65
F	CaF <sub>2</sub>		0.00
SO <sub>4</sub> <sup>2-</sup>	CaSO <sub>4</sub> ·2H <sub>2</sub> O	1478.00	0.00
CO <sub>3</sub> <sup>2-</sup>	CaCO <sub>3</sub>		0.00
TSS	n/a		0.00
<b>Total</b>			<b>442.73</b>

**Solids Generation = 0.48 g/L**  
(includes 5.0 % lime enerts)  
(includes 5.0 % unreacted lime solids)

**Lime Requirements**

Lime Utilization = 95.0 %  
Available CaO = 95.0 %

Lime use = 0.488 g Ca(OH)<sub>2</sub>/L  
Lime use = 0.388 g lime (CaO)/L

## MASS BALANCE: URS OPERATING SERVICES INC.

GLADSTONE SAMPLE 1 - ARD TREATMENT

FEED 114 m<sup>3</sup>/hr

Streams															
Slurry	Vol. flow rate	m <sup>3</sup> /hr	114	0.26	0.77	0.51	0.26	6.73	6.98	0.23	119.56	6.91	0.19	114	0.97
	Mass flow rate	ton/hr	114	0.29	0.87	0.58	0.29	7.87	8.17	0.23	121.95	8.09	0.22	114	0.97
	S.G		1.00	1.14	1.14	1.14	1.14	1.17	1.17	1.00	1.02	1.17	1.17	1.00	1.00
	pH		2.40	<12	<12	<12	<12	9.30	<12	5-7	9.30	9.30	9.30	9.30	5-7
Solids	Vol. Flow rate	m <sup>3</sup> /hr	0.00	0.02	0.07	0.05	0.02	0.82	0.84	0.00	0.87	0.84	0.02	0.00	0.00
	Mass Flow rate	ton/hr	0.00	0.06	0.17	0.12	0.06	1.97	2.03	0.00	2.08	2.02	0.05	0.00	0.00
	S.G		0.00	2.50	2.50	2.50	2.50	2.40	2.40	0.00	2.40	2.40	2.40	0.00	0.00
	% Solids of Total Wt		0.00	20.00	20.00	20.00	20.00	25.00	24.82	0.00	1.71	25.00	25.00	0.00	0.00
Liquid	Vol. Flow rate	m <sup>3</sup> /hr	114	0.23	0.70	0.47	0.23	5.91	6.14	0.23	119.87	6.07	0.16	114	0.97
	Mass Flowrate	ton/hr	114	0.23	0.70	0.47	0.23	5.91	6.14	0.23	119.87	6.07	0.16	114	0.97
	S.G		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	% Liquid of Total Wt		100.00	80.00	80.00	80.00	80.00	75.00	75.18	100.00	98.29	75.00	75.00	100.00	100.00

# MASS BALANCE: URS OPERATING SERVICES INC.

GLADSTONE SAMPLE 1 - ARD TREATMENT

FEED 227 m<sup>3</sup>/hr

Streams															
Slurry	Vol. flow rate	m <sup>3</sup> /hr	227	0.51	1.54	1.10	0.44	13	14	0.23	239	14	0.37	227	1
	Mass flow rate	ton/hr	227	0.58	1.75	1.17	0.58	16	16	0.23	244	16	0.44	227	1
	S.G		1.00	1.14	1.14	1.06	1.32	1.17	1.18	1.00	1.02	1.17	1.17	1.00	1.00
	pH		2.4	<12	<12	<12	<12	9.3	<12	5-7	9.3	9.3	9.3	9.3	5-7
Solids	Vol. Flow rate	m <sup>3</sup> /hr	0.00	0.05	0.14	0.05	0.09	2	2	0.00	2	2	0.05	0.00	0
	Mass Flow rate	ton/hr	0.00	0.12	0.35	0.12	0.23	4	4	0.00	4	4	0.11	0.00	0.00
	S.G		0.00	2.50	2.50	2.50	2.50	2.40	2.41	0.00	2.41	2.40	2.40	0.00	0.00
	% Solids of Total Wt		0	20	20	20	20	25	26	0	1.76	25	25	0	0
Liquid	Vol. Flow rate	m <sup>3</sup> /hr	227	0.47	1.40	1.05	0.35	12	12	0.23	239	12	0.33	227	1
	Mass Flowrate	ton/hr	227	0.47	1.40	1.05	0.35	12	12	0.23	239	12	0.33	227	1
	S.G		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	% Liquid of Total Wt		100	80	80	80	80	75	74	100	98.2	75	75	100	100



### Aeration Requirements

**URS OPERATING SERVICES INC.**

**GLADSTONE SAMPLE 1 - ARD TREATMENT**

Total Flow In =	114 m <sup>3</sup> /hr
Total Iron Content =	86.5 mg/L
Total Ferrous Iron =	0.18 kmol/hr
Percent Ferrous Iron =	<b>100 %</b>
O <sub>2</sub> Required for Ferrous =	1.41 kg/hr
Total Manganese Content =	52.8 mg/L
Total Manganese =	0.109 kmol/hr
O <sub>2</sub> Required for Manganese =	1.7 kg/hr
Total O <sub>2</sub> Required =	3.2 kg/hr
Oxygen Transfer Efficiency =	<b>20 %</b>
Aeration required =	<b>54 m<sup>3</sup>/hour</b>
	<b>= 32 SCFM</b>

## **APPENDIX B2.**

### **Process Design Parameters for Sample 2**

## URS OPERATING SERVICES INC.

### GLADSTONE SAMPLE 2 - ARD TREATMENT

#### Conceptual Design : 6541 m<sup>3</sup>/day

##### Flowrate

Normal Flowrate	6541 m <sup>3</sup> /day
Normal Flowrate	273 m <sup>3</sup> /hr
Normal Flowrate	1200 GPM
Max. Flowrate	10902 m <sup>3</sup> /day
Max. Flowrate	454 m <sup>3</sup> /hr
Max. Flowrate	2000 GPM
Feed pH	3.3
Operating pH	9.0

##### Solids

Solids Generations	0.21 g/L
Solids Generations-Max	0.21 g/L
Normal Solids Generations	0.057 ton/hr
Max. Solids Generations	0.095 ton/hr
Normal Sludge Recycle Ratio	56 :1
Max. Sludge Recycle Ratio	56 :1
Percent Solids in Sludge	25.0 %
Sludge Pulp Density	1.17
Clarifier Feed S.G	1.02

##### Vessels - Residence Times

Reactor Vessels	60 minutes
Lime Sludge Mix Tank	4 minutes
Recycle Water Tank	10 minutes
Clarifier Upflow Ratio	1.10

##### Lime

Lime Require (CaO)	0.17 kg/m <sup>3</sup>
Lime Requirements (Ca(OH) <sub>2</sub> )	0.23 kg/m <sup>3</sup>
Lime Concentration	20 %
Lime Solid S.G	2.50
Lime Requirement (Ca(OH) <sub>2</sub> )	0.063 ton/hr
Lime Requirement (CaO)	0.047 ton/hr
Lime Recycle IN Ratio	3
Lime Recycle RETURN Ratio	2
Lime to TANKS Ratio	1
Lime Slurry Tanks Holding Time	24 hrs.

##### Flocculent

Flocculent Addition	1 mg/L
Flocculent Addition	0.3 kg/hr
Flocculent Concentration	0.05 %
Flocculent Make Up Water pH	5-7

**Water Quality and Sludge Generation Prediction  
URS OPERATING SERVICES INC.  
GLADSTONE SAMPLE 2 - ARD TREATMENT**

Ion	Hydroxide Formula	Mass of Ion Present (mg/L)	Mass of Precip. (mg/L)
Al	Al(OH) <sub>3</sub>	10.93	31.59
Ag	AgOH	0.00	0.00
As	As(OH) <sub>3</sub>	0.00	0.00
Bi	Bi(OH) <sub>3</sub>	0.00	0.00
Ca	Ca(OH) <sub>2</sub>	189.48	0.00
Cd	Cd(OH) <sub>2</sub>	0.03	0.04
Cu	Cu(OH) <sub>2</sub>	1.13	1.74
Fe	Fe(OH) <sub>3</sub>	25.74	49.26
Pb	Pb(OH) <sub>2</sub>	0.04	0.04
Mg*	Mg(OH) <sub>2</sub>	16.02	28.84
Mn	MnO <sub>2</sub>	20.68	32.72
Ni	Ni(OH) <sub>2</sub>	0.03	0.04
S*	CaSO <sub>4</sub> ·2H <sub>2</sub> O		0.00
Sb	Sb(OH) <sub>3</sub>	0.00	0.00
Se	Se(OH) <sub>4</sub>	0.00	0.00
Si	Si(OH) <sub>2</sub>	12.79	28.28
Zn	Zn(OH) <sub>2</sub>	12.05	18.31
F	CaF <sub>2</sub>		0.00
SO <sub>4</sub> <sup>2-</sup> *	CaSO <sub>4</sub> ·2H <sub>2</sub> O	808.00	0.00
CO <sub>3</sub> <sup>2-</sup>	CaCO <sub>3</sub>		0.00
TSS	n/a		0.00
<b>Total</b>			<b>190.88</b>

**Solids Generation = 0.21 g/L**  
(includes 5.0 % lime enerts)  
(includes 5.0 % unreacted lime solids)

**Lime Requirements**

Lime Utilization = 95.0 %  
Available CaO = 95.0 %

Lime use = 0.219 g Ca(OH)<sub>2</sub>/L  
Lime use = 0.174 g lime (CaO)/L

## MASS BALANCE: URS OPERATING SERVICES INC.

GLADSTONE SAMPLE 2 - ARD TREATMENT

FEED 273 m<sup>3</sup>/hr

Streams															
Slurry	Vol. flow rate	m <sup>3</sup> /hr	273	0.28	0.83	0.55	0.28	10.86	11.14	0.55	280.52	11.06	0.19	273	1.64
	Mass flow rate	ton/hr	273	0.31	0.94	0.63	0.31	12.72	13.03	0.55	286.13	12.94	0.23	273	1.64
	S.G		1.00	1.14	1.14	1.14	1.14	1.17	1.17	1.00	1.02	1.17	1.17	1.00	1.00
	pH		3.30	<12	<12	<12	<12	9.30	<12	5-7	9.30	9.30	9.30	9.30	5-7
Solids	Vol. Flow rate	m <sup>3</sup> /hr	0.00	0.03	0.08	0.05	0.03	1.32	1.35	0.00	1.37	1.35	0.02	0.00	0.00
	Mass Flow rate	ton/hr	0.00	0.06	0.19	0.13	0.06	3.18	3.24	0.00	3.30	3.24	0.06	0.00	0.00
	S.G		0.00	2.50	2.50	2.50	2.50	2.40	2.40	0.00	2.40	2.40	2.40	0.00	0.00
	% Solids of Total Wt		0.00	20.00	20.00	20.00	20.00	25.00	24.88	0.00	1.15	25.00	25.00	0.00	0.00
Liquid	Vol. Flow rate	m <sup>3</sup> /hr	273	0.25	0.75	0.50	0.25	9.54	9.79	0.55	282.83	9.71	0.17	273	1.64
	Mass Flowrate	ton/hr	273	0.25	0.75	0.50	0.25	9.54	9.79	0.55	282.83	9.71	0.17	273	1.64
	S.G		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	% Liquid of Total Wt		100.00	80.00	80.00	80.00	80.00	75.00	75.12	100.00	98.85	75.00	75.00	100.00	100.00

# MASS BALANCE: URS OPERATING SERVICES INC.

GLADSTONE SAMPLE 2 - ARD TREATMENT

FEED 454 m<sup>3</sup>/hr

Streams															
<b>Slurry</b>															
Vol. flow rate	m <sup>3</sup> /hr	454	0.46	1.38	0.97	0.41	18	19	0.55	467	18	0.32	455	2	
Mass flow rate	ton/hr	454	0.52	1.57	1.05	0.52	21	22	0.55	477	22	0.38	455	2	
S.G		1.00	1.14	1.14	1.08	1.28	1.17	1.17	1.00	1.02	1.17	1.17	1.00	1.00	
pH		3.3	<12	<12	<12	<12	9.3	<12	5-7	9.3	9.3	9.3	9.3	5-7	
<b>Solids</b>															
Vol. Flow rate	m <sup>3</sup> /hr	0.00	0.04	0.13	0.05	0.08	2	2	0.00	2	2	0.04	0.00	0	
Mass Flow rate	ton/hr	0.00	0.10	0.31	0.13	0.19	5	5	0.00	6	5	0.09	0.00	0.00	
S.G		0.00	2.50	2.50	2.50	2.50	2.40	2.40	0.00	2.40	2.40	2.40	0.00	0.00	
% Solids of Total Wt		0	20	20	20	20	25	25	0	1.17	25	25	0	0	
<b>Liquid</b>															
Vol. Flow rate	m <sup>3</sup> /hr	454	0.42	1.26	0.92	0.33	16	16	0.55	471	16	0.28	455	2	
Mass Flowrate	ton/hr	454	0.42	1.26	0.92	0.33	16	16	0.55	471	16	0.28	455	2	
S.G		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
% Liquid of Total Wt		100	80	80	80	80	75	75	100	98.8	75	75	100	100	

### Aeration Requirements

URS OPERATING SERVICES INC.

GLADSTONE SAMPLE 2 - ARD TREATMENT

Total Flow In =	273 m <sup>3</sup> /hr
Total Iron Content =	25.7 mg/L
Total Ferrous Iron =	0.13 kmol/hr
Percent Ferrous Iron =	100 %
O <sub>2</sub> Required for Ferrous =	1.01 kg/hr
Total Manganese Content =	20.7 mg/L
Total Manganese =	0.103 kmol/hr
O <sub>2</sub> Required for Manganese =	1.6 kg/hr
Total O <sub>2</sub> Required =	2.6 kg/hr
Oxygen Transfer Efficiency =	20 %
Aeration required =	46 m <sup>3</sup> /hour
	= 27 SCFM

## **APPENDIX C1**

### **Equipment List for Sample 1**



## Mechanical Equipment List

URS OPERATING SERVICES INC.  
GLADSTONE SAMPLE 1 - ARD TREATMENT

Description	Motor hp <sup>1</sup>	Type	Capacity/Size	Material
Sludge/Lime Mix Tank Agitator				C.S.
Lime Reactor #1 Tank Agitator				C.S.
Lime Reactor #2 Tank Agitator				C.S.
Lime Slurry Storage Tank Agitator				
Clarifier Rake Mechanism				C.S.
Lime Slurry Pump #1		Centrifugal	2 m <sup>3</sup> /hr	
Lime Slurry Pump #2		Centrifugal	2 m <sup>3</sup> /hr	
Sludge Recycle Pump #1 V.S.D.		Centrifugal	7 m <sup>3</sup> /hr	
Sludge Recycle Pump #2 V.S.D.		Centrifugal	7 m <sup>3</sup> /hr	
Sludge Purge Pump		Centrifugal	0.4 m <sup>3</sup> /hr	
Flocculant/Lime Area Sump Pump		Cantilever	4 m <sup>3</sup> /hr	
Sludge Pump Room Sump Pump		Cantilever	4 m <sup>3</sup> /hr	
Sludge/Lime Mix tank			2.8 ft Ø x 4 ft High	C.S.
Lime Reactor Tank #1			16.7 ft Ø x 21.7 ft High	C/S
Lime Reactor Tank #2			16.7 ft Ø x 21.7 ft High	C/S
Clarifier Tank			39 ft Ø	C/S
Lime Slurry Storage Tank			6.5 ft Ø x 3.6 ft High	C/S

<sup>1</sup>Typically equipment specifications are provided by Vendors; however, in this case the Vendors were not consulted. The motor power were estimated with a theoretical model. And, CEMI's database was also cross referenced to estimate motor power.

## **APPENDIX C2**

### **Equipment List for Sample 2**

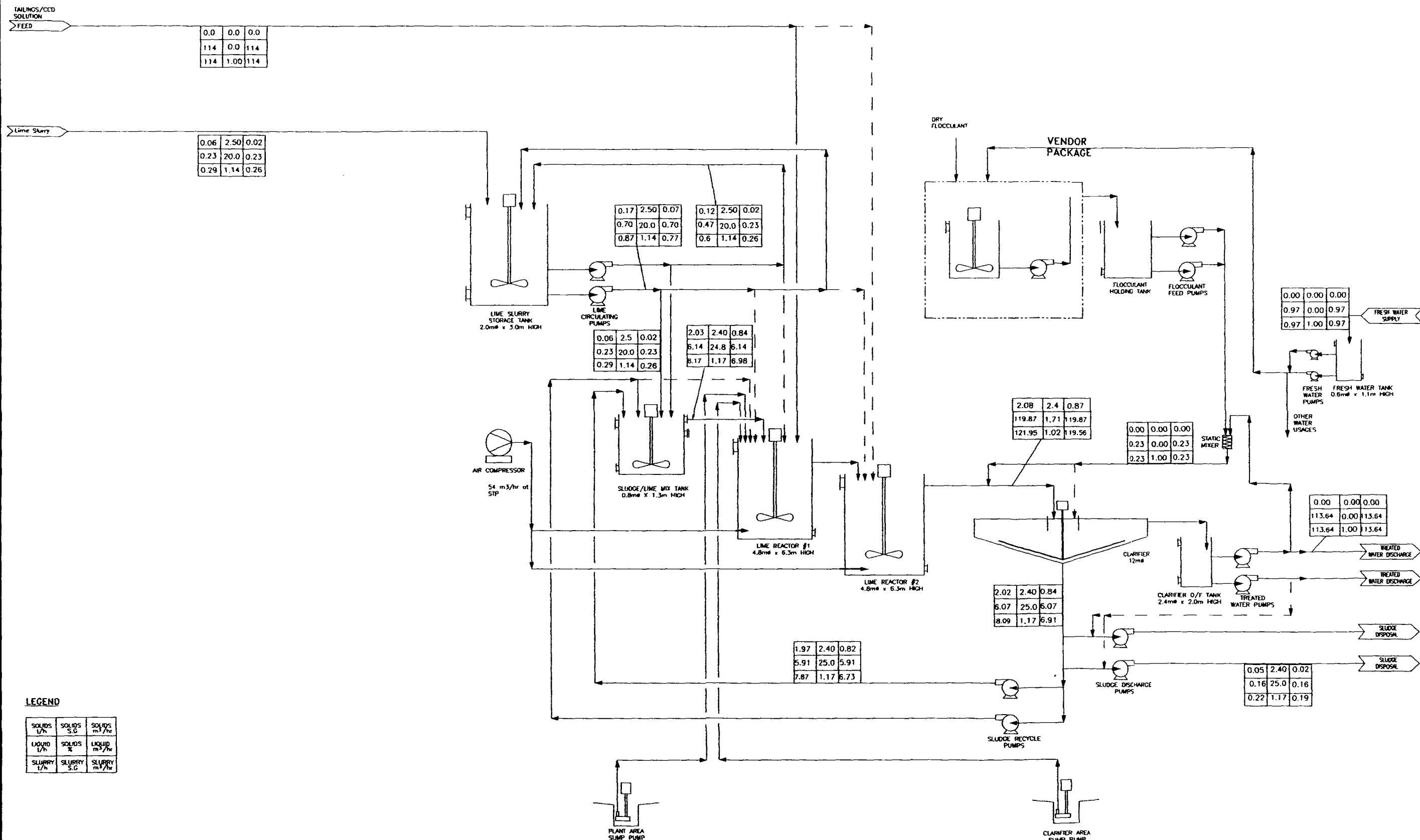
**Mechanical Equipment List**  
**URS OPERATING SERVICES INC.**  
**GLADSTONE SAMPLE 2 - ARD TREATMENT**

Description	Motor hp <sup>1</sup>	Type	Capacity/Size	Material
Sludge/Lime Mix Tank Agitator Lime Reactor #1 Tank Agitator Lime Reactor #2 Tank Agitator Lime Slurry Storage Tank Agitator Clarifier Rake Mechanism				c.s. c.s. c.s.  c.s.
Lime Slurry Pump #1 Lime Slurry Pump #2		Centrifugal Centrifugal	1 m <sup>3</sup> /hr 1 m <sup>3</sup> /hr	
Sludge Recycle Pump #1 V.S.D. Sludge Recycle Pump #2 V.S.D.		Centrifugal Centrifugal	11 m <sup>3</sup> /hr 11 m <sup>3</sup> /hr	
Sludge Purge Pump		Centrifugal	0.3 m <sup>3</sup> /hr	
Flocculant/Lime Area Sump Pump Sludge Pump Room Sump Pump		Cantilever Cantilever	4 m <sup>3</sup> /hr 4 m <sup>3</sup> /hr	
Sludge/Lime Mix tank Lime Reactor Tank #1 Lime Reactor Tank #2			3.2 ft Ø x 4.9 ft High 19.4 ft Ø x 24.3 ft High 19.4 ft Ø x 24.3 ft High	c.s. c/s c/s
Clarifier Tank			59 ft Ø	c/s
Lime Slurry Storage Tank			6.7 ft Ø x 3.9 ft High	c/s

<sup>1</sup>Typically equipment specifications are provided by Vendors; however, in this case the Vendors were not consulted. The motor power were estimated with a theoretical model. And, CEMI's database was also cross referenced to estimate motor power.

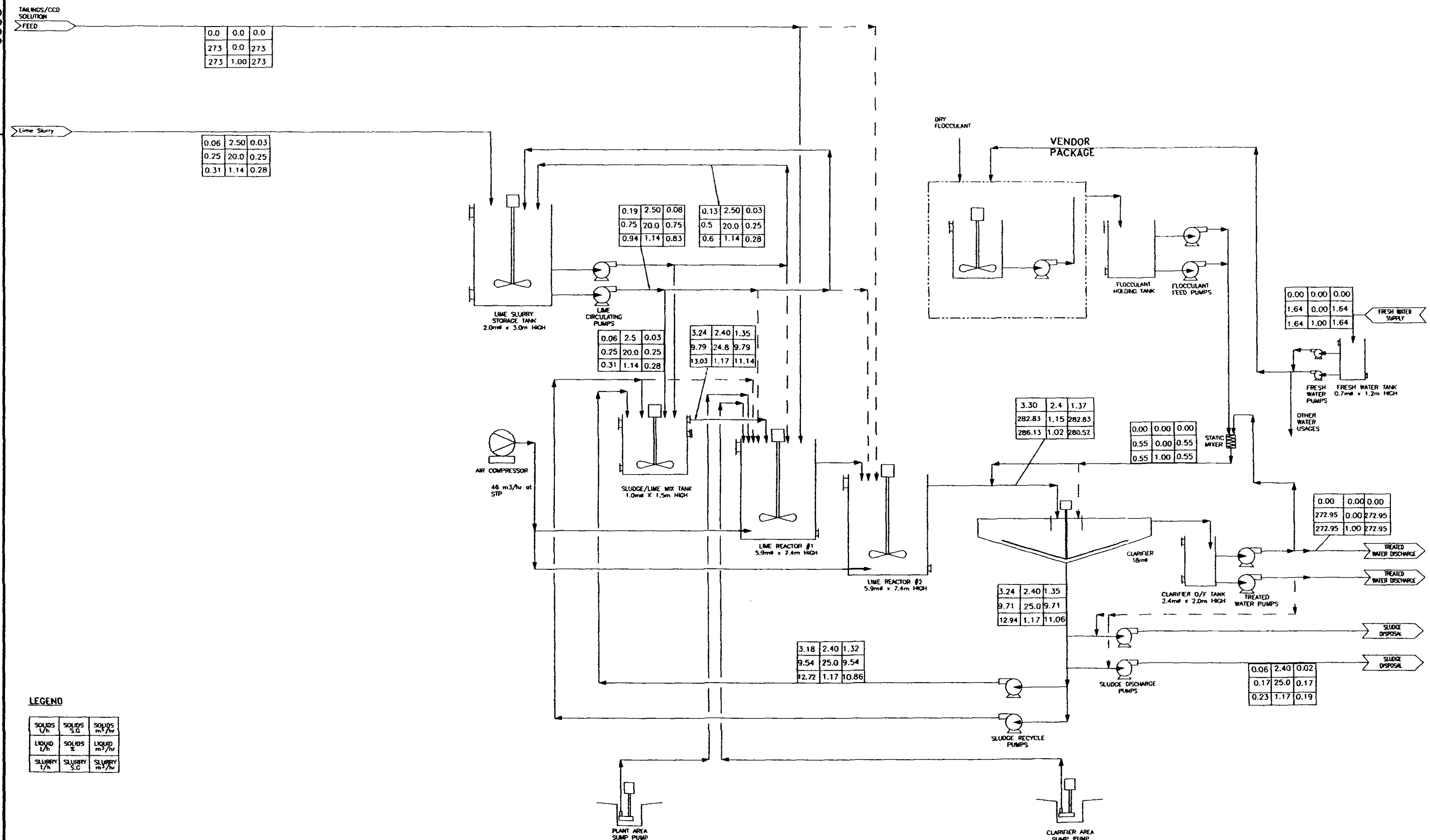
## **APPENDIX D**

### **Conceptual Process Flowsheet**



LEGEND		
SOLIDS l/h	SOLIDS S.G	SOLIDS m <sup>3</sup> /hr
LIQUID l/h	SOLIDS %	LIQUID m <sup>3</sup> /hr
SLURRY l/h	SLURRY S.G	SLURRY m <sup>3</sup> /hr

[illegible]

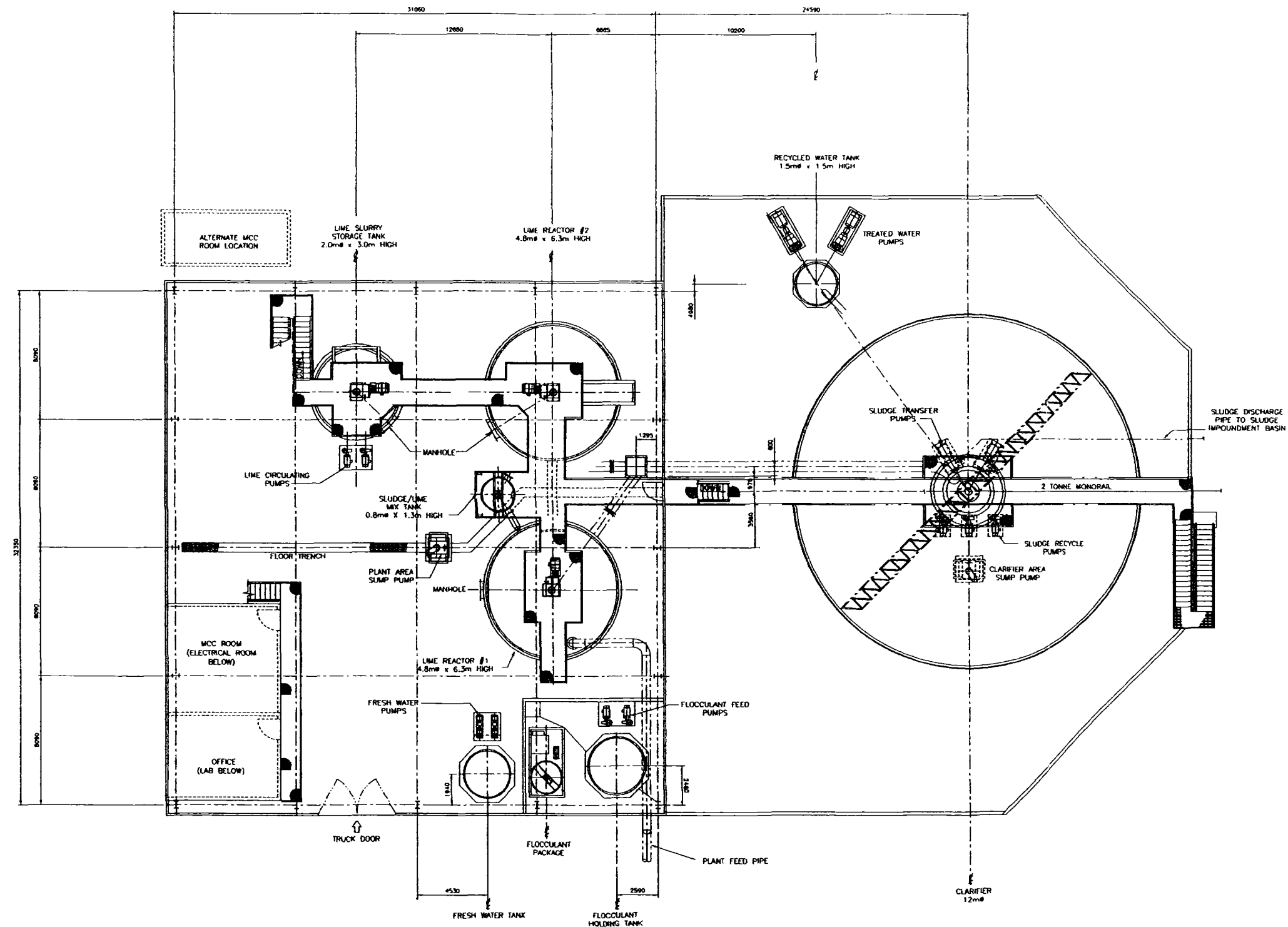
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## **APPENDIX E**

### **Conceptual General Arrangement Plan**

**Drawings No**

CAD FILE NAME: 0555-M01 LAST UPDATE:

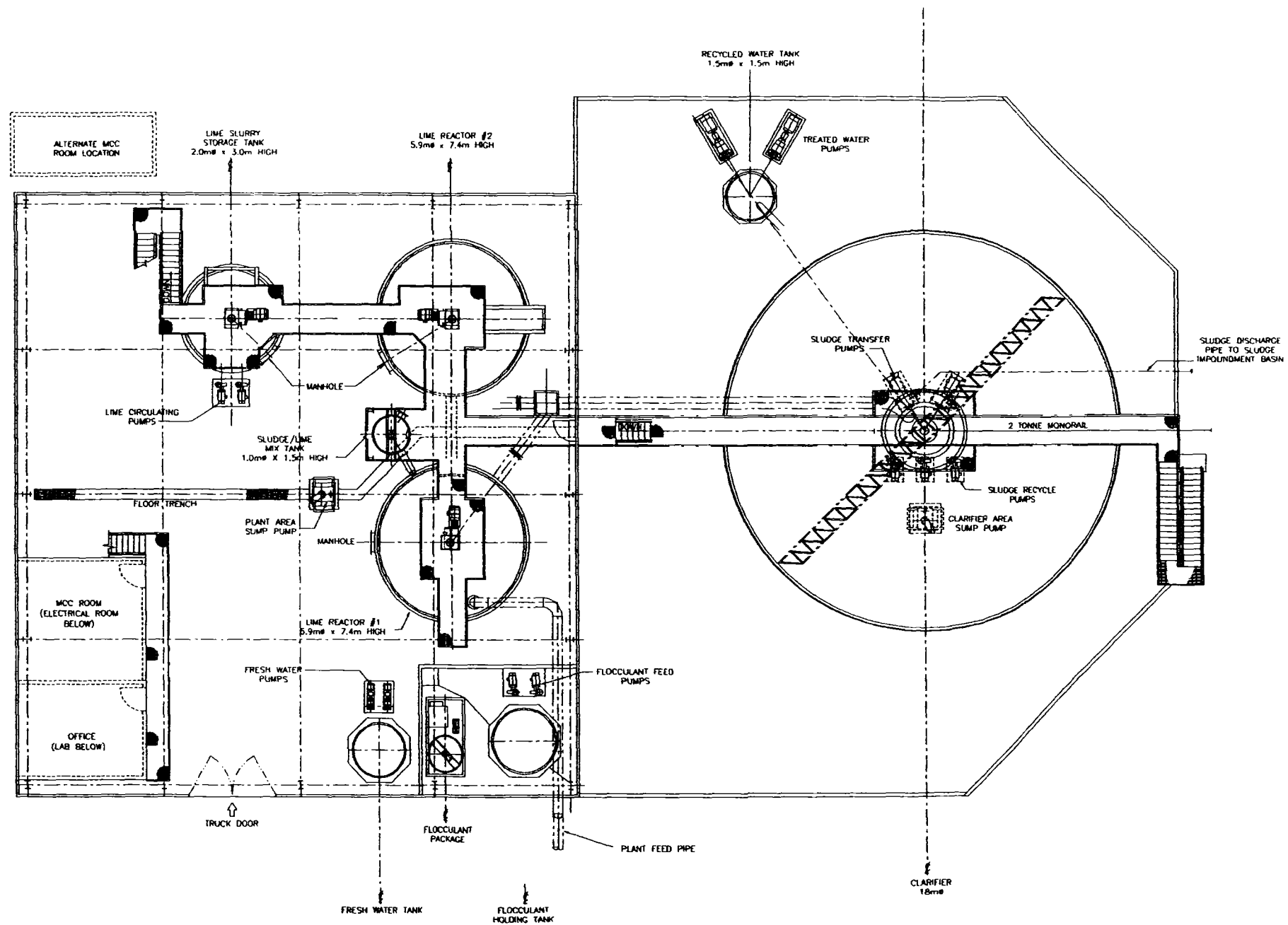
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0555-M02

Drawing No.

CAD FILE NAME: 0555-M02 LAST UPDATE:




**Comments on “Sampling Activities Report” and “Water Treatment Evaluation Report” - Gladstone Treatment Plant TBA  
URS Operating Services, Inc.**

*Brian Caruso, Ph.D., P.E.  
Hazardous Substances Technical Liaison  
Office of Research and Development  
Region 8*

August 24, 2006

**Comments on Sampling Activities Report**

Comment 1. 2.0 History, last paragraph. Figure 2 is missing. A sleeve is provided, and I assume that the detailed sample location figure in the “Water Treatment Evaluation Report” is the same figure as this (or should be), but the figure should be provided for detailed sample location information in this report.

Comment 2. Page 4, 4.0 Field Activities. This section should include a brief discussion of collection and rationale for quality assurance/quality (QA/QC) control samples. Although in Section 5.0 on page 7 it is mentioned that duplicate samples were collected, this information should be in Section 4.0 with more details on how, where, how many, etc.

Comment 3. Page 6, 1<sup>st</sup> bullet. An explanation should be provided as to why the sampling location was changed.

Comment 4. Page 7, 5.0 Sample Analysis and Results, 2<sup>nd</sup> paragraph. See Comment 1 regarding duplicate samples.

Comment 5. Page 10, 1<sup>st</sup> partial paragraph from section 6.2, last sentence. Why were values of 50% lower or 200% greater than historical values selected, and are these referring to flows or concentrations?

Comment 6. Page 11, 6.3, 1<sup>st</sup> sentence. Referring to Comment 5, these values for differences are not the same as those mentioned in the previous comment. Please clarify what differences were used and why.

**Comments on Water Treatment Evaluation Report**

Comment 1. Page ES-4, Table ES-1. It looks like the information in the columns “WTP Location” and “Sludge Disposal Option” are reversed and should be corrected.

Comment 2. Page 6, 1<sup>st</sup> paragraph, 2<sup>nd</sup> sentence. This sentence stating that the standards are expected to be determined by June 2006 is out of date and should be corrected.

Comment 3. Page 6, Table 1. The locations of these segments (Cement Creek and Animas below Silverton?) should be explicitly stated in the table. Also, TVS should be defined in the footnotes.

Comment 4. Page 7, Table 2. The table should explicitly state that the standards for total recoverable aluminum and dissolved zinc are the same for both acute and chronic (not just “acute/chronic”, the meaning of which is not clear).

Comment 5. Page 7, Table 3. The table should state where the TVS are for (Cement Creek?) and the difference between “None” and “- - -” (which should be defined in the footnotes).

Comment 6. Page 18, 4.3. Need more information on bio treatment technologies, such as sulfate reducing bacteria bioreactors, sulfide precipitation using biological sulfide generation (such as Bioteq), etc.

Comment 7. Page 23, 1<sup>st</sup> full paragraph. The statement that sulfide precipitation is not proven in large-scale practice is not really true, since Bioteq (also in conjunction with Phelps Dodge in Arizona) has at least 4 or 5 such plants in operation. This should have been considered further, or at least the statement tempered.

Comment 8. Page 33, last paragraph. Why was the treatability study performed on water collected during September 2005 instead of one of the other sampling events? State the justification for this event here.

Comment 9. Page 42, 1<sup>st</sup> paragraph, 2<sup>nd</sup> sentence. What would the additional costs be for the experienced designer and construction personnel based on this type of field design?

Comment 10. Page 45, 2<sup>nd</sup> full paragraph, 3<sup>rd</sup> sentence. Regarding the assumption that none of the piping would be buried, what are the disadvantages or impacts of not burying the piping? This should be discussed briefly in the report.

Comment 11. Page 51, 8.0. A more detailed evaluation of the treatment impacts or effectiveness on CC48 and A72 should be included in the next steps.



Todd Hennis  
<mogul1882@yahoo.com>  
10/23/2007 11:40 AM

To Sabrina Forrest/EPR/R8/USEPA/US@EPA  
cc  
bcc  
Subject Gladstone water treatment plant.

Sabrina-

I've spent the morning with the docs. Here are my comments.

It's actually Gold King Mines Corp. not Gold King Corp. Not of real consequence.

San Juan Corp owns the existing water treatment plant equipment. The State disclaimed any interest, and we got a deed from Gold King.

The BLM Cadastral survey at the Gladstone is incorrect, and we are challenging it. However, we will make the Gladstone site work if need be.

It's pretty clear now that the 500 gpm scenario is out of date. I don't have the flow measures, but I suspect this year we are dealing with 800 gpm, and there is no real way to know how this will top out. I think we are probably looking at a 1200 gpm plant. Additional, the piping costs are probably understated due to material cost increases (oil related), flow increases, and the absolute maintenance nightmare that piping will be. In all honesty, I cannot visualize a pipeline working from Gold King, between size, plugging up constantly, avalanches and just sheer inaccessibility. The only pipeline that I can really see working is from the red and Bonita, being totally buried, and having cleanouts about every 200 feet.

We are starting to see non-availability of design firms, etc. If there is a real crunch, Lyntek Inc. in Denver may be able to do this.

On the Gladstone scenario for settling ponds, the ponds need to be moved NW by 100 to 150 feet if at all possible to try to keep the plant on the Harrison Millsite.

Table A-2 in the Adendum. Taking 2005 results vs. my 2006 was not a totally valid comparison. Things change. I quickly checked the Oct 2006 results vs. my July 2006 results for Zn and Cu, and they correlate a lot better. The pH differential on the Red and Bonita I believe is due to the sampling location. I hate to admit it, but mine was right at the very point of outflow vs. the ones taken down in the ditch. The water really gets oxygenated in between, and I believe we have a pH drop due to this. As it stands, Table A-2 infers I either took incorrect samples, or that I did something to the samples. I did not.

Going through the report, I could not find the two biggest needs:

Comparison of 20 year costs in NPV terms for settling ponds vs HDS, expressed for Gladstone vs. Gladstone and Success vs. Success

Also, the settling pond scenarios with a thickener added to increase density of sludges. Sunnyside had in 1985 a 100 foot long thickener in the Quonset Hut that was never [placed into operation due to Standard Metals bankruptcy, and it was sold by the bankruptcy trustee.

Now for the controversial part: If we 20 year cost the 1200 gpm plant, this will open up the scenario for removing the first two bulkheads in the American Tunnel and just treating the 900 gpm or so (once the mountain drains down) from the first bulkhead forward. realistically looking at the whole global solution scenarios for the Sunnyside Mine Pool problem, this is the only thing that makes sense from an operational standpoint. I cannot overstate the difficulties and extreme long term costs of pipelines. There will be scale blockages that cannot be roto-routed out, and sections of line will either have to be dug out and replaced or just replaced on surface. The avalanche damage damage to surface lines will also be a huge factor (how would you like to replace a 600 feet of line torn out on the mountainside from Gold King 7 down the gulch?. The American Tunnel option is really the only thing that makes sense to me (and others knowledgeable in Silverton) from a long term operational standpoint. I am speaking from experience, since today's project is rescuing a drilling rig from Ross Basin before the drifts and avalanches close it off for the season.

For San Juan Corp.,

Todd C. Hennis, Pres.

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